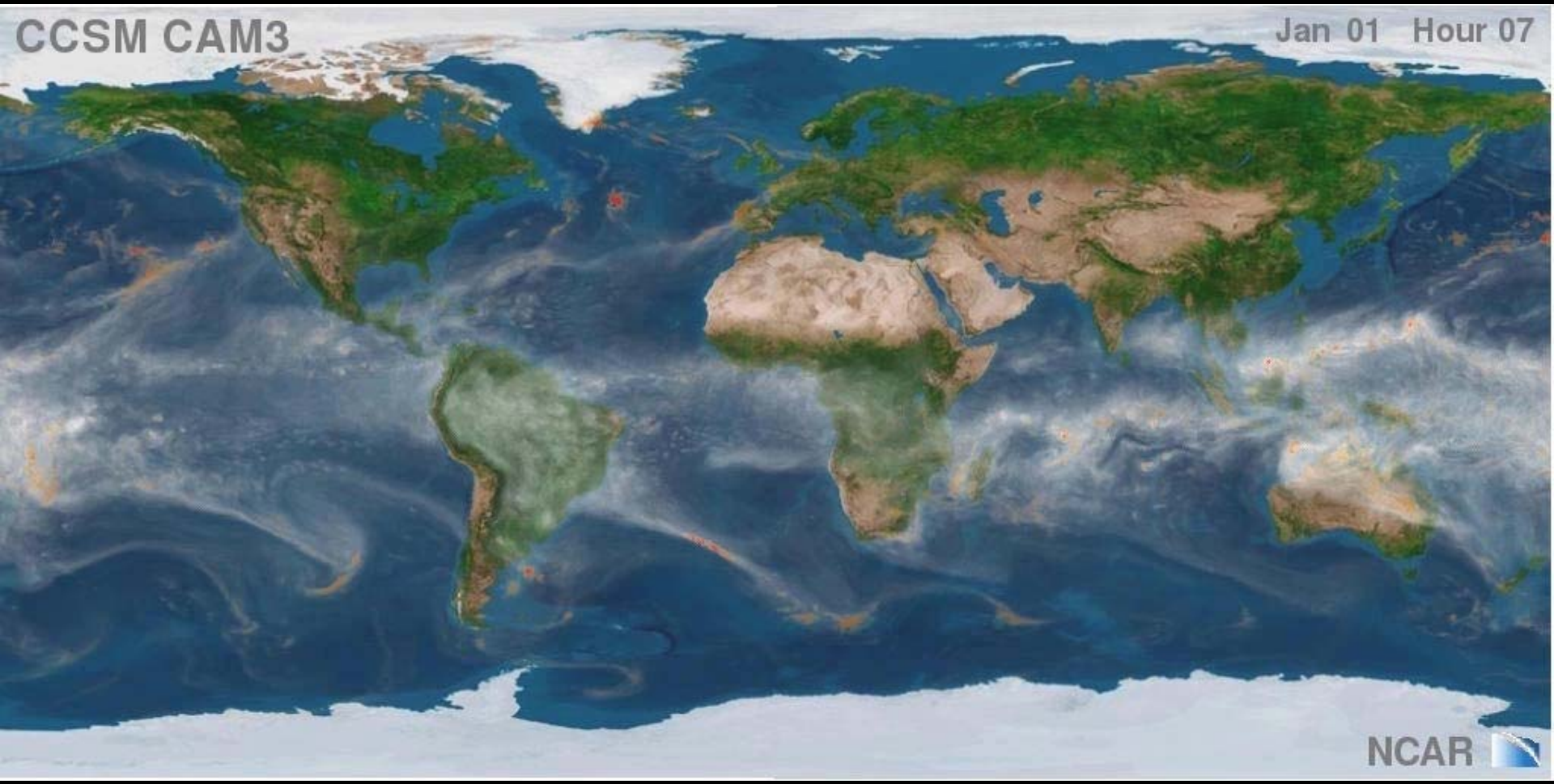
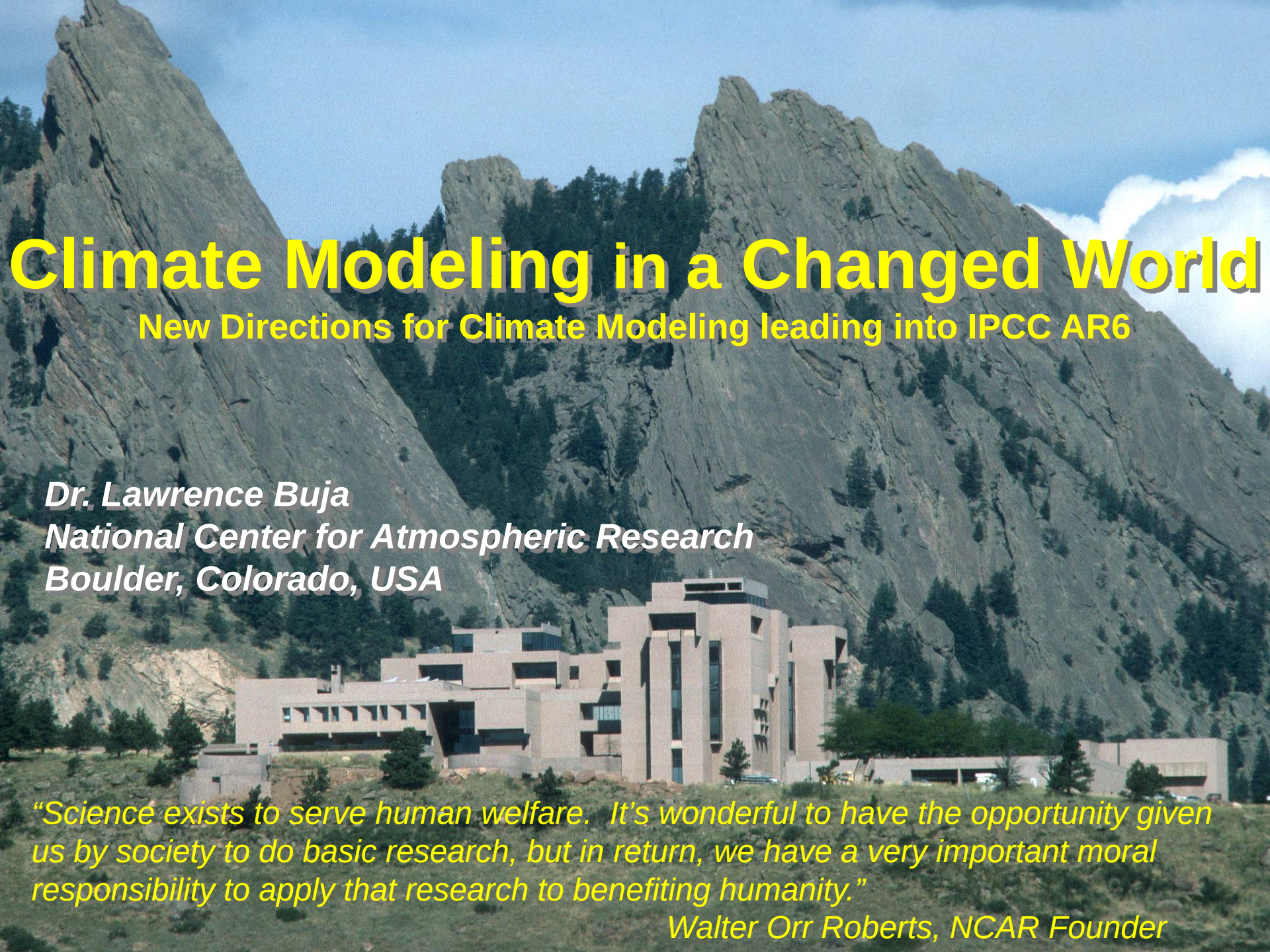
Climate Modeling in a Changed World

New Directions for Climate Modeling leading into IPCC AR5



CAM T341- Jim Hack

Dr. Lawrence Buja
National Center for Atmospheric Research
Boulder, Colorado, USA



Climate Modeling in a Changed World

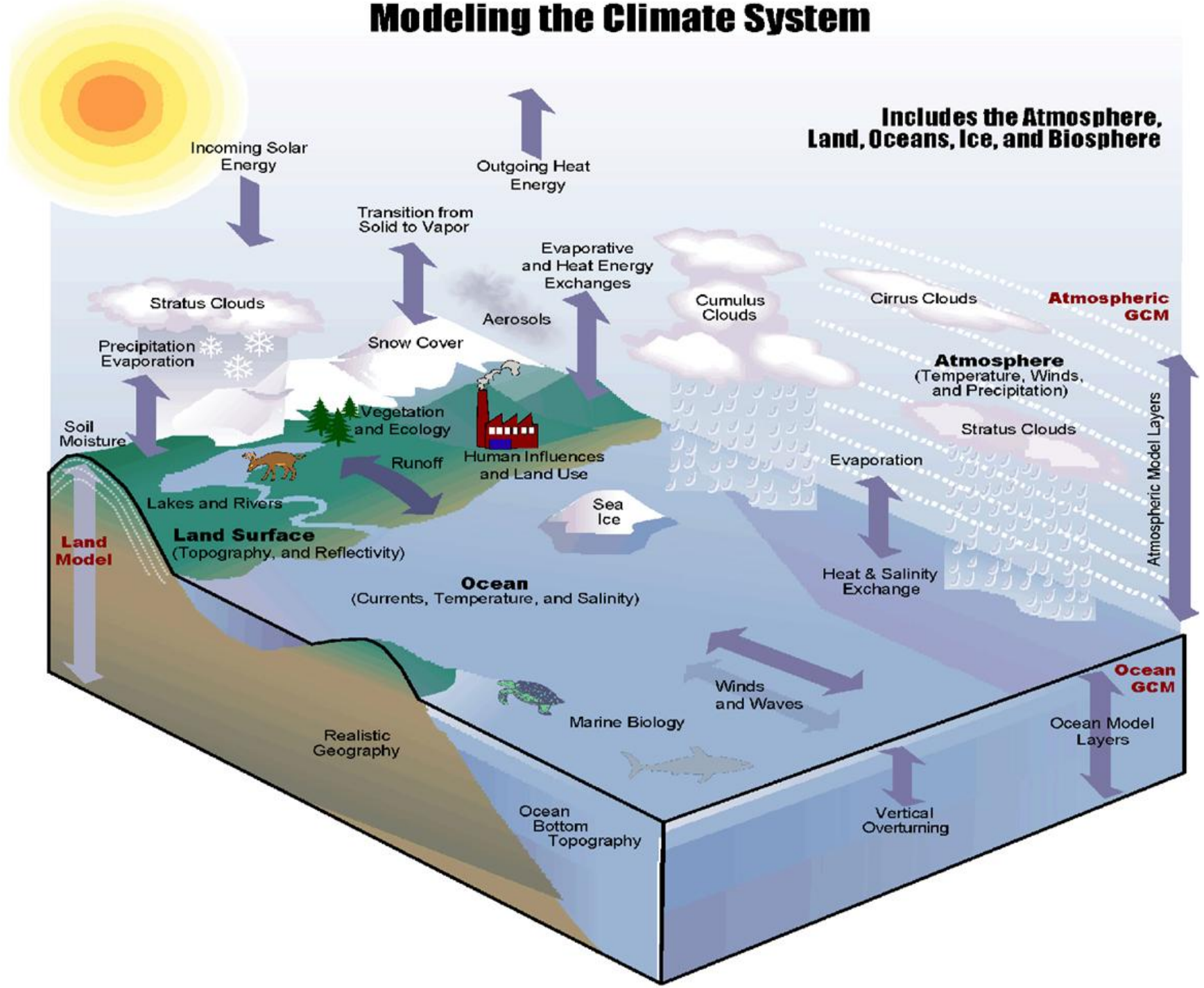
New Directions for Climate Modeling leading into IPCC AR6

Dr. Lawrence Buja
National Center for Atmospheric Research
Boulder, Colorado, USA

"Science exists to serve human welfare. It's wonderful to have the opportunity given us by society to do basic research, but in return, we have a very important moral responsibility to apply that research to benefiting humanity."

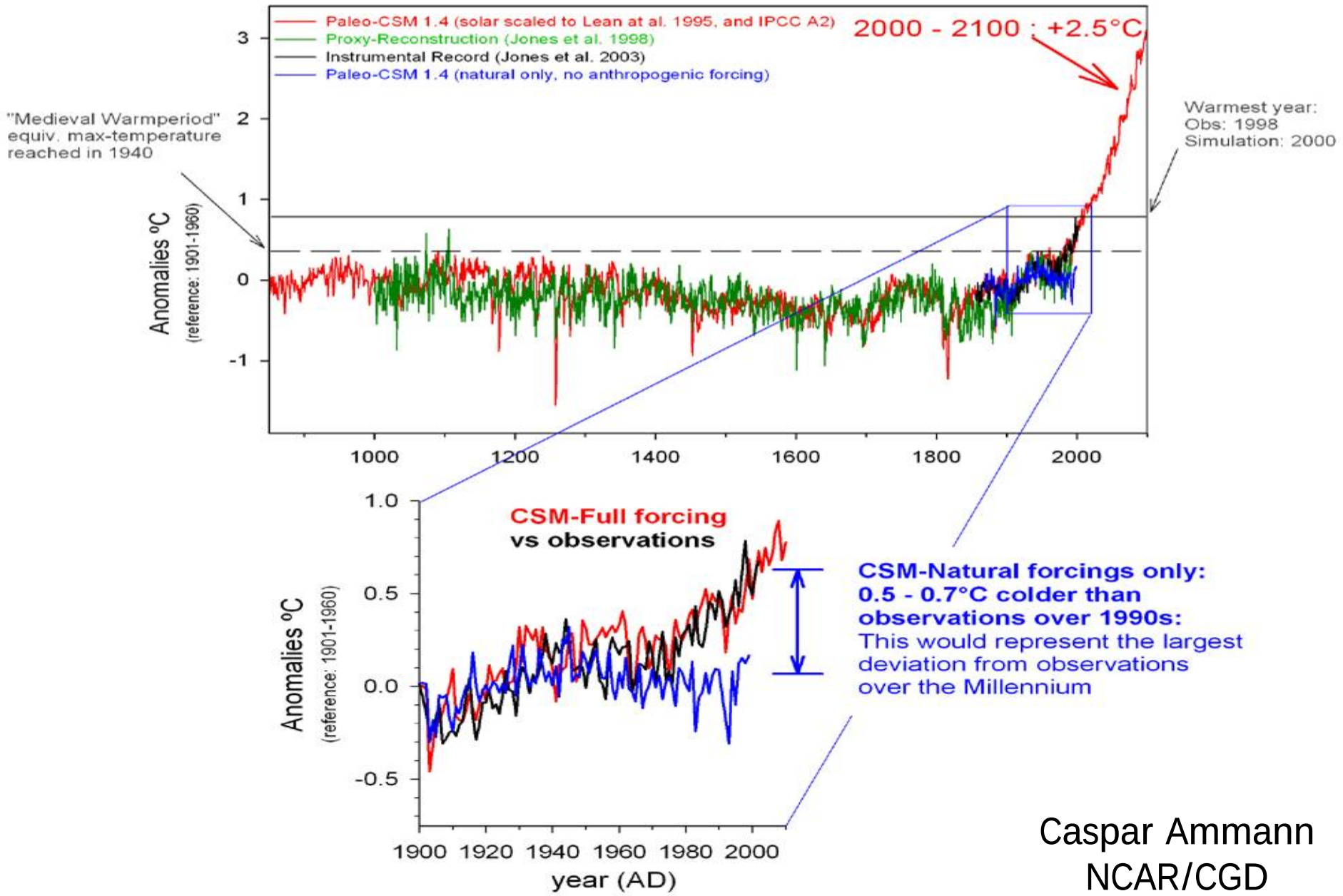
Walter Orr Roberts, NCAR Founder

Modeling the Climate System

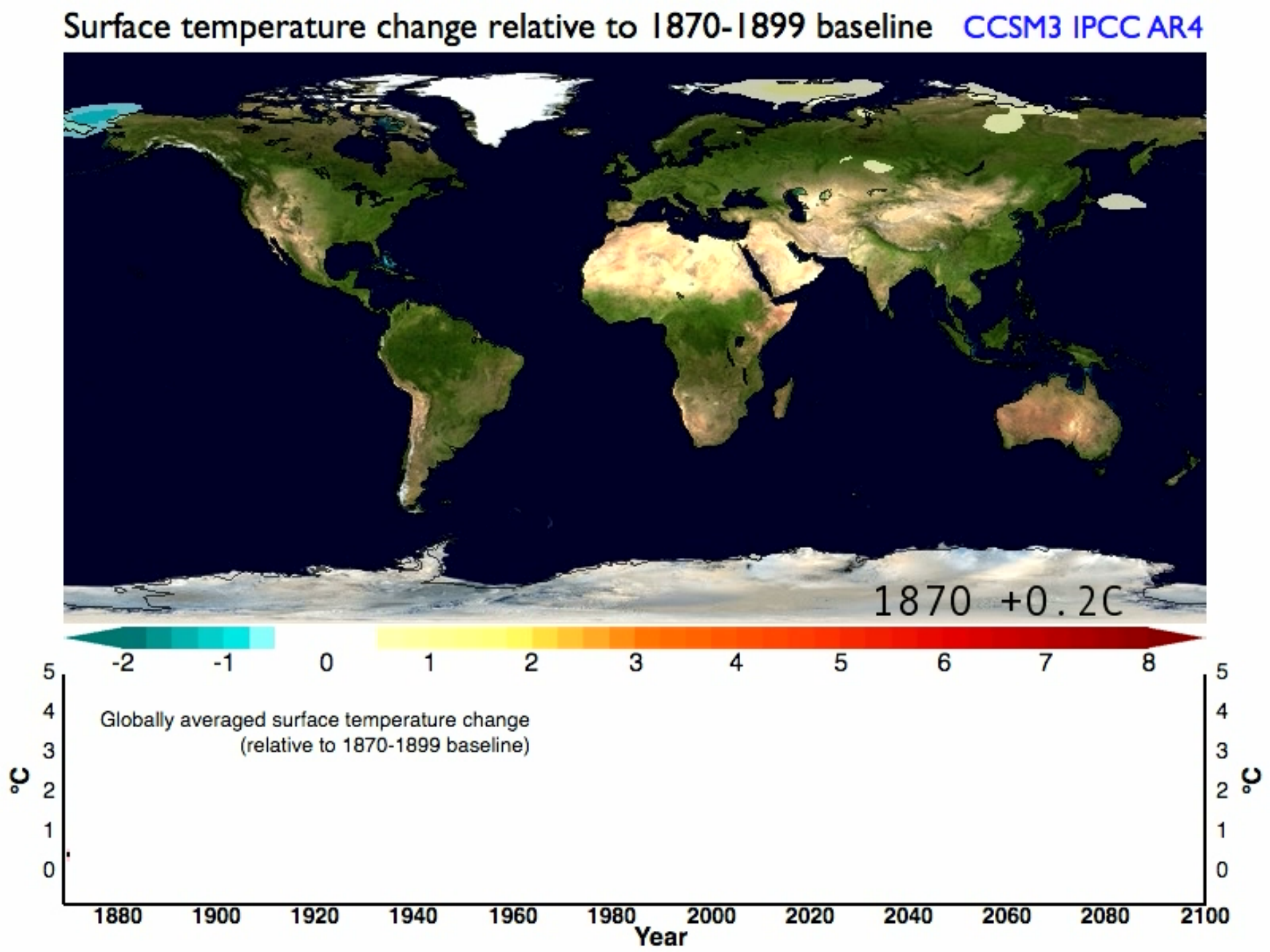


CCSM: The NCAR Climate Model

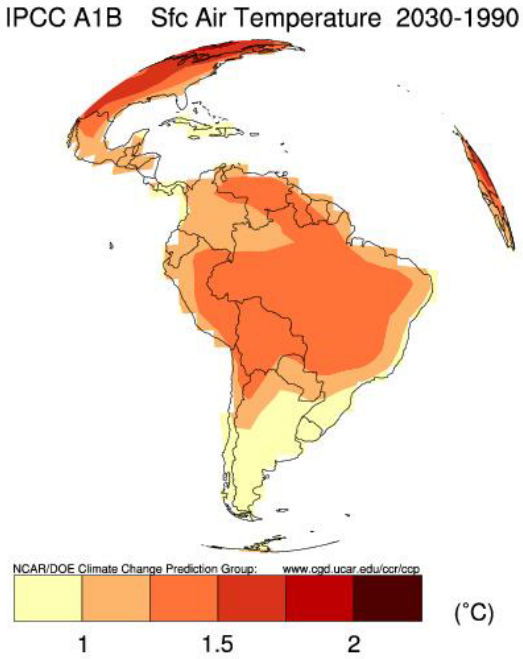
Climate of the last Millennium

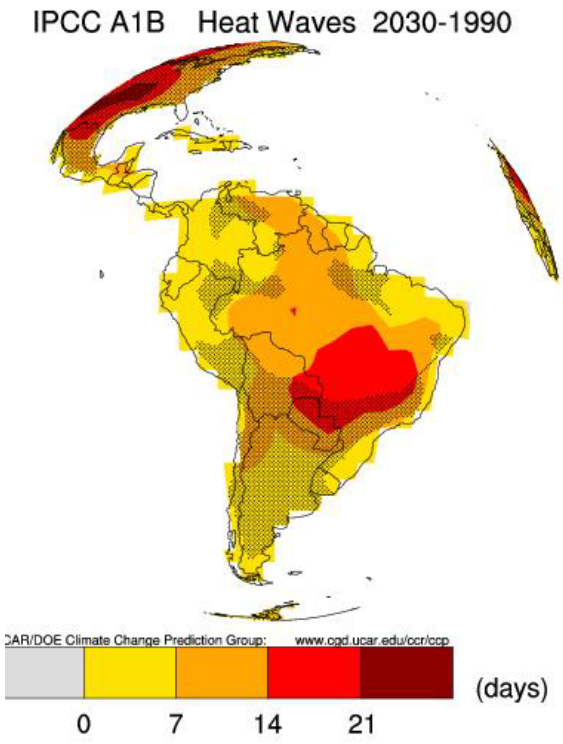


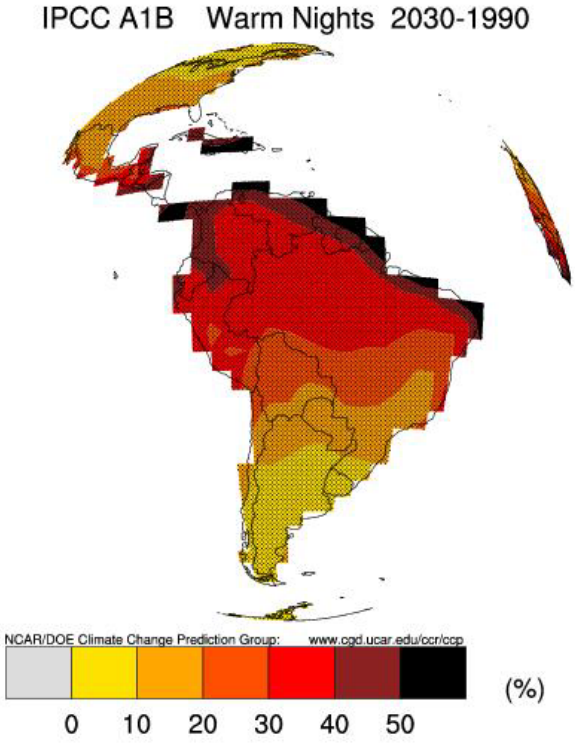
Caspar Ammann
NCAR/CGD

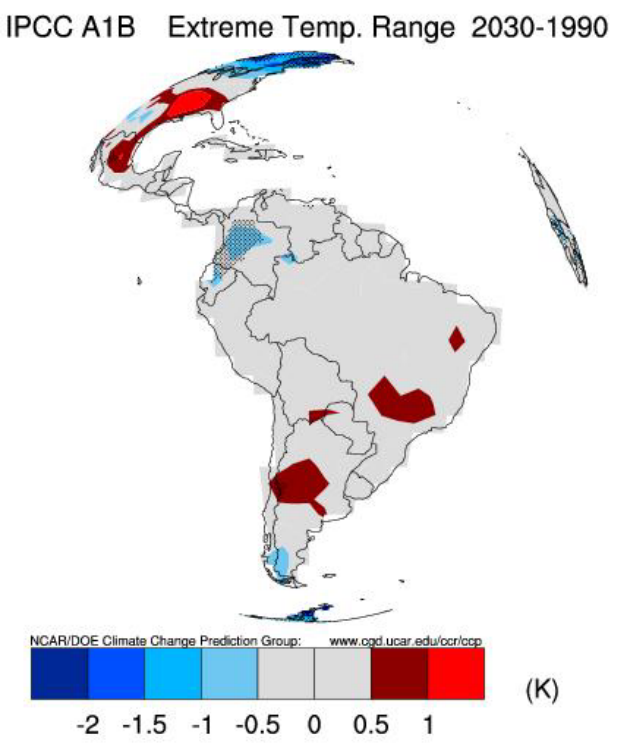

Surface temperature change relative to 1870-1899 baseline
CCSM3 IPCC AR4
1870 +0.2C
-2
-1
0
1
2
3
4
5
6
7
8
Globally averaged surface temperature change
(relative to 1870-1899 baseline)
°C
°C
0
1
2
3
4
5
1880
1900
1920
1940
1960
1980
2000
2020
2040
2060
2080
2100
Year

Temperature at 2030 Averages and Extremes

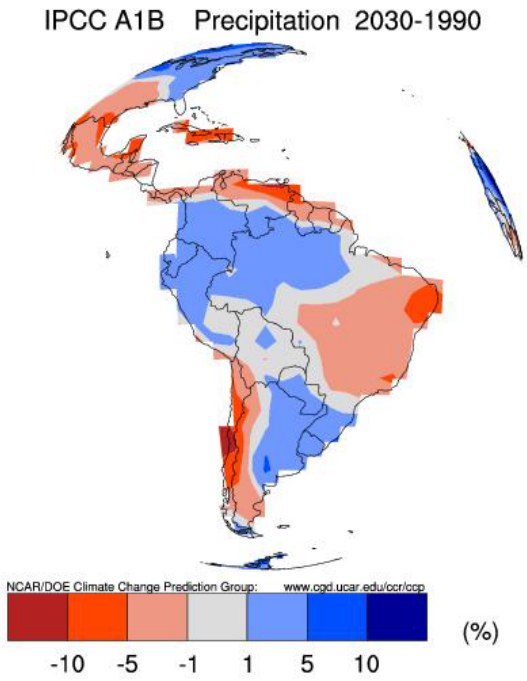


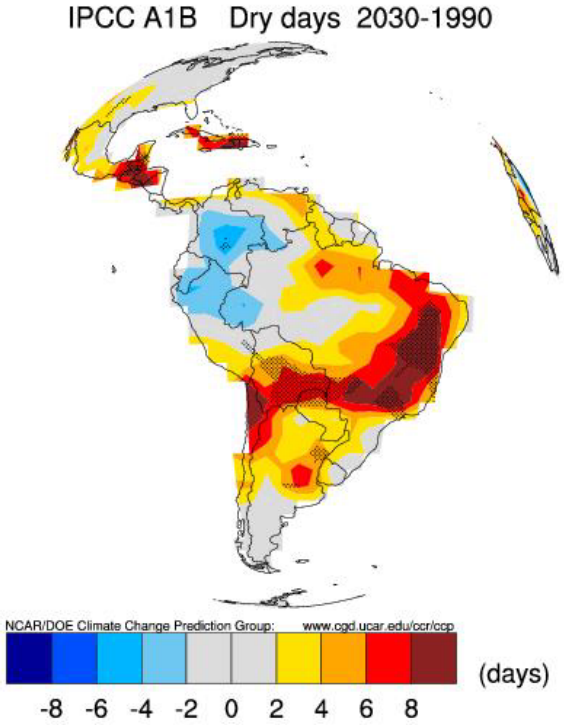


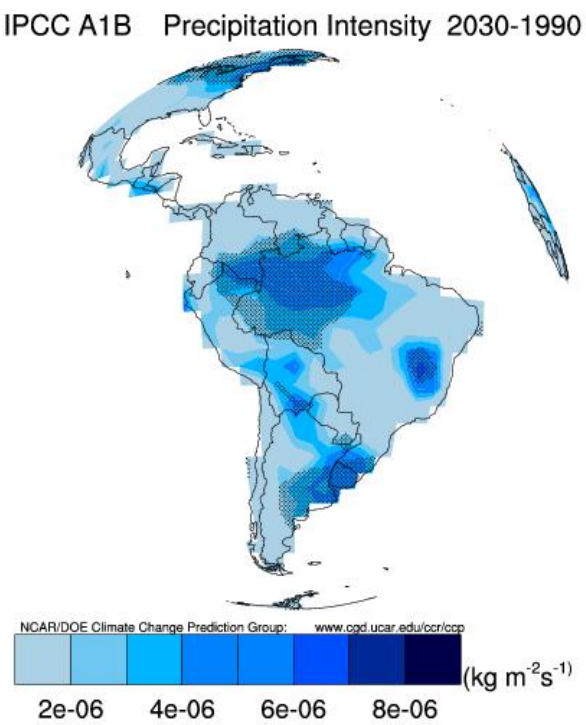


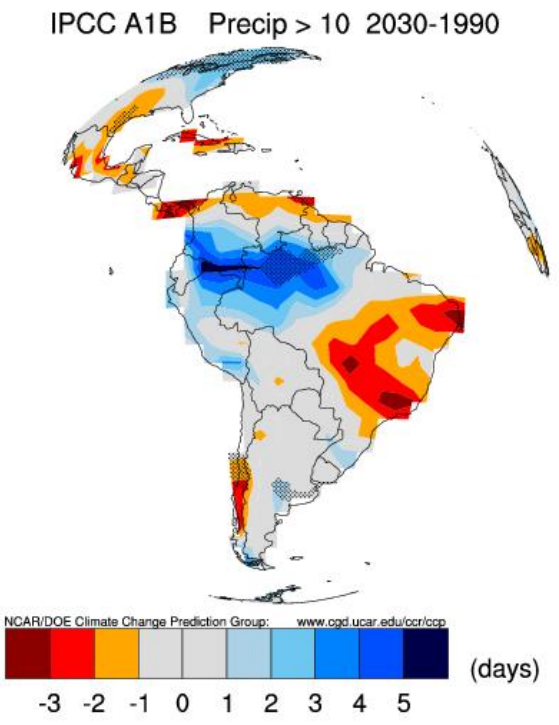


Precipitation at 2030 Averages and Extremes

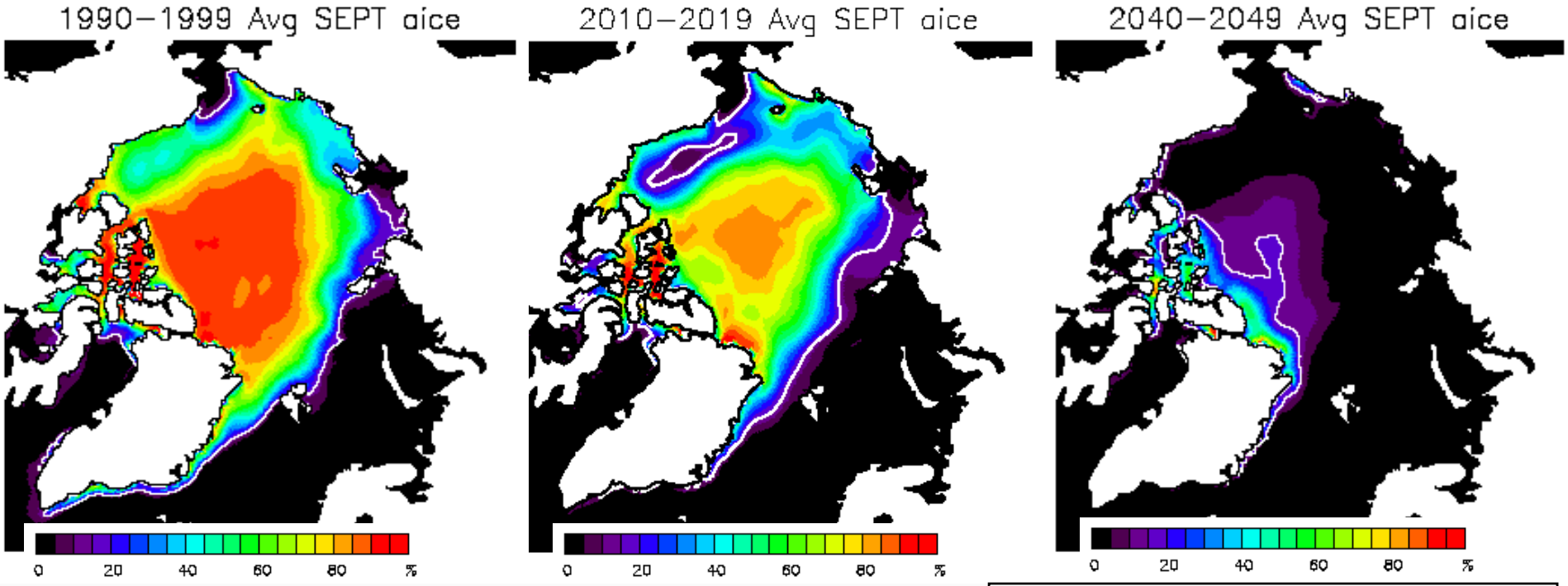


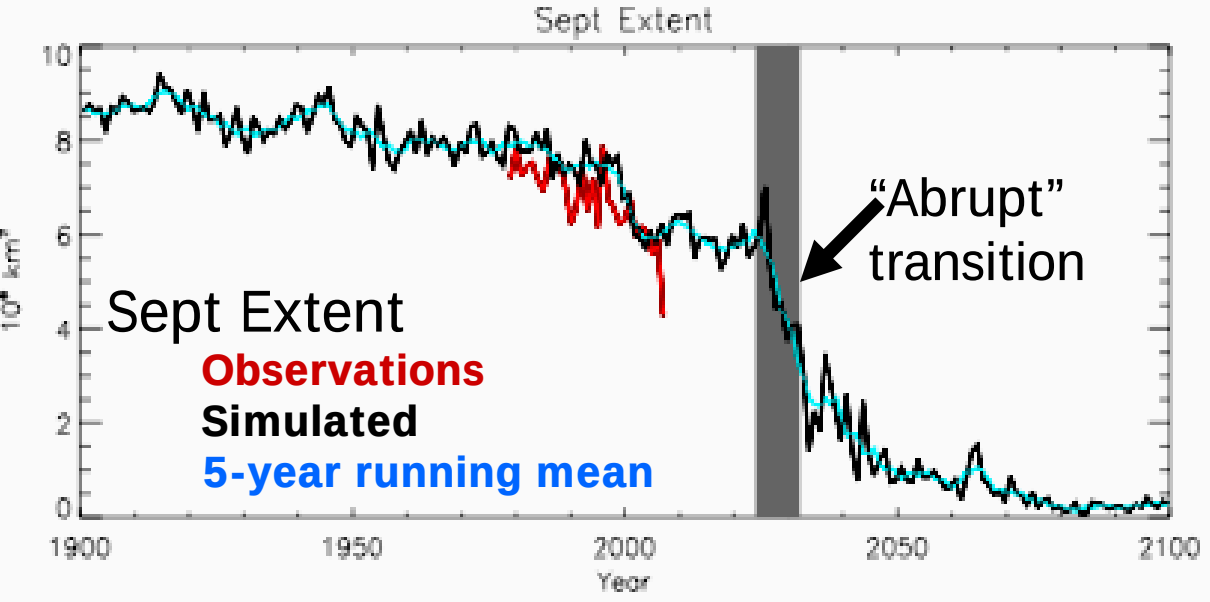






Future Change: Abrupt Transitions in Sea Ice



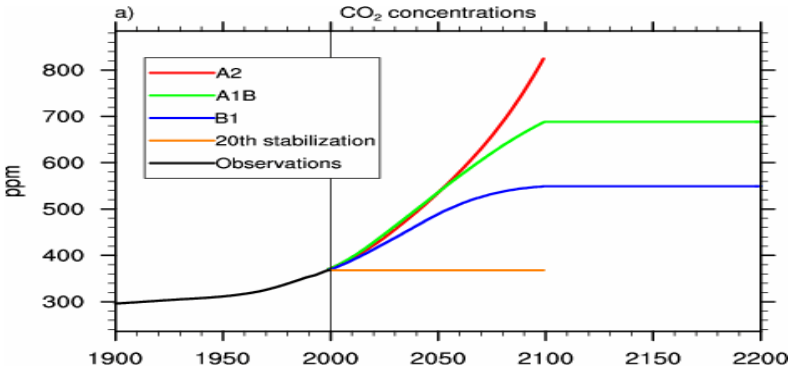


- Gradual forcing results in abrupt Sept ice decrease
- Extent decreases from 80 to 20% coverage in 10 years.
- Relevant factors:
  - Ice thinning
  - Arctic heat transport
  - Albedo feedback
- Winter maximum shows smaller, gradual decreases

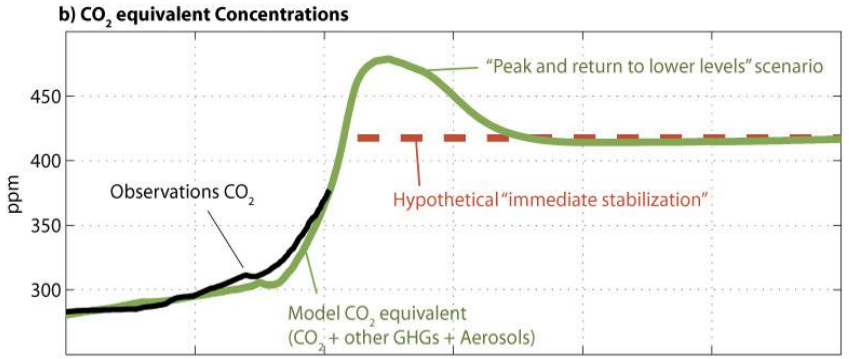
Climate Change Epochs

Before | **IPCC AR4** | **After**

- Attribute sources of historical warming
- Project range of possible non-mitigated future warming from SRES scenarios
- Quantify climate change commitment



- Project adaptation needs/stresses under various mitigation scenarios
- Time-evolving regional climate change on short and long-term timeframes
- Quantify carbon cycle feedbacks



Before AR4: The question was simple:

"Is anthropogenic climate change occurring?"

Now much harder questions:

"What is the detailed impact on human and natural ecosystems and what is the range of possible mitigation options/costs/outcomes?"

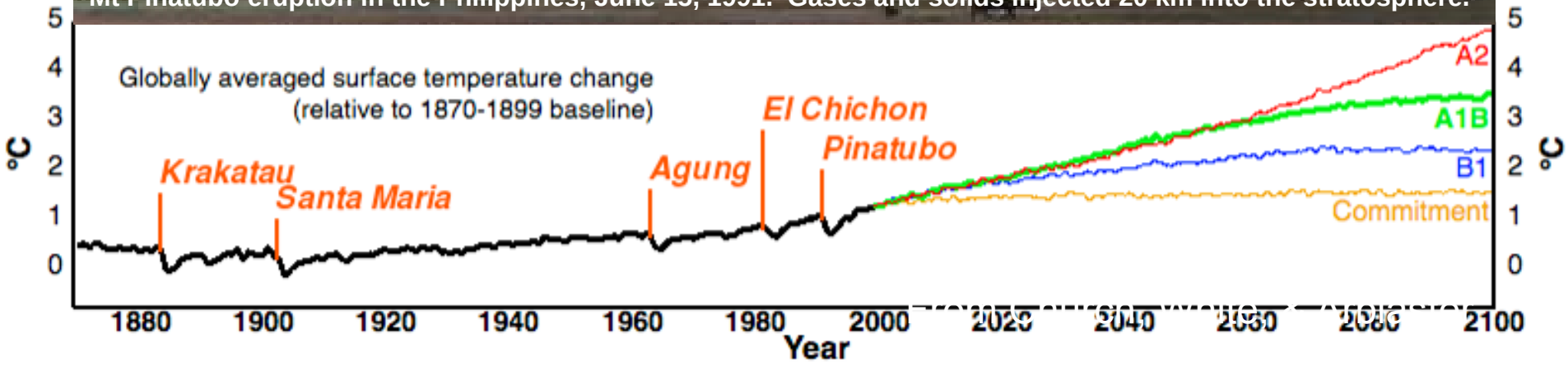
Geoengineering strategies

- Space mirrors, (Wood, Angel)
- High Altitude Sulphur injections
- Seeding stratocumulus clouds to brighten clouds
- Sequestration of CO2
- Iron Fertilization, ...

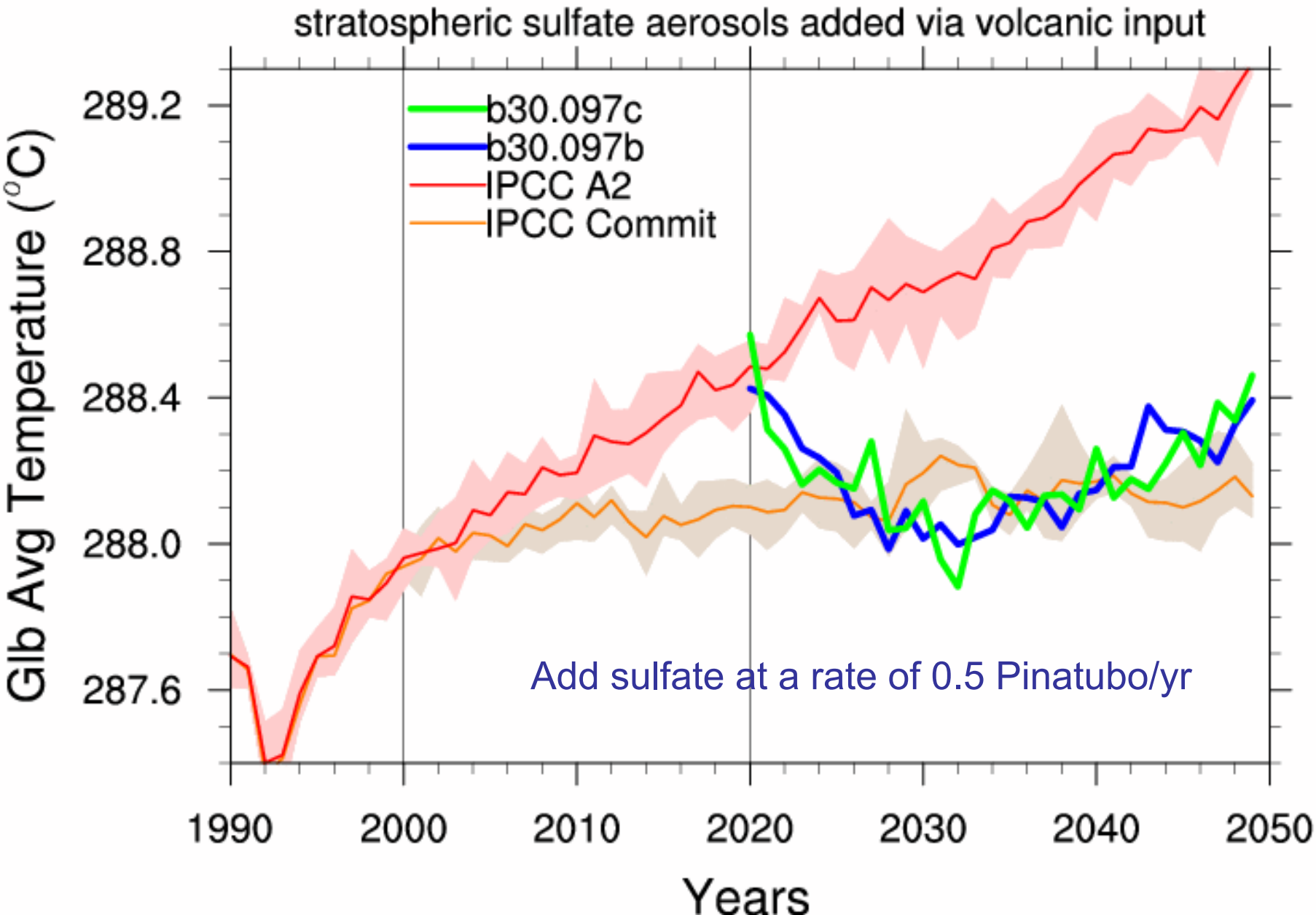
Phil Rasch NCAR

We are not proposing that geo-engineering be carried out!
We are proposing that the implications should be carefully explored.

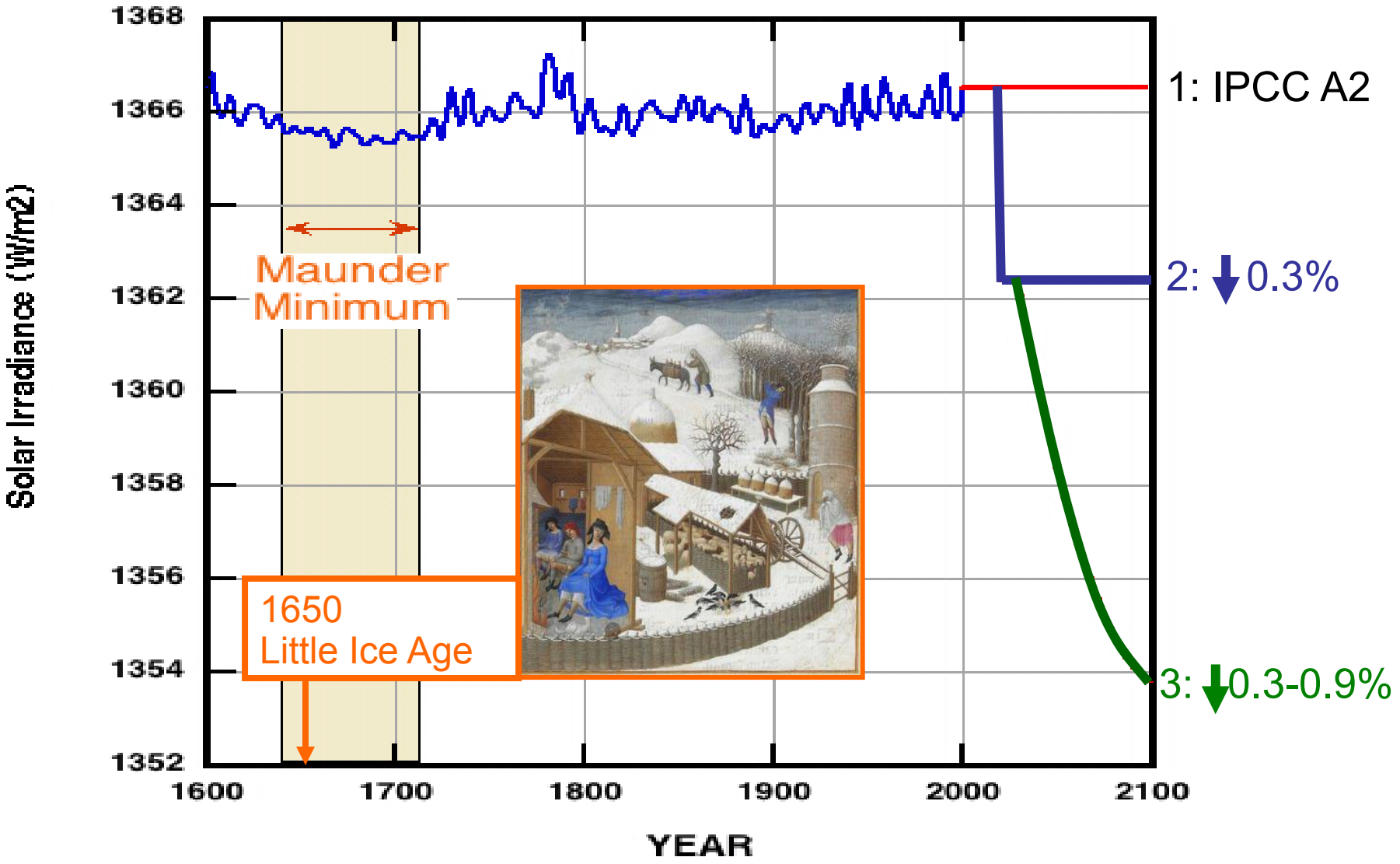
Mt Pinatubo eruption in the Philippines, June 15, 1991. Gases and solids injected 20 km into the stratosphere.



NCAR CCSM3 Geoengineering Run

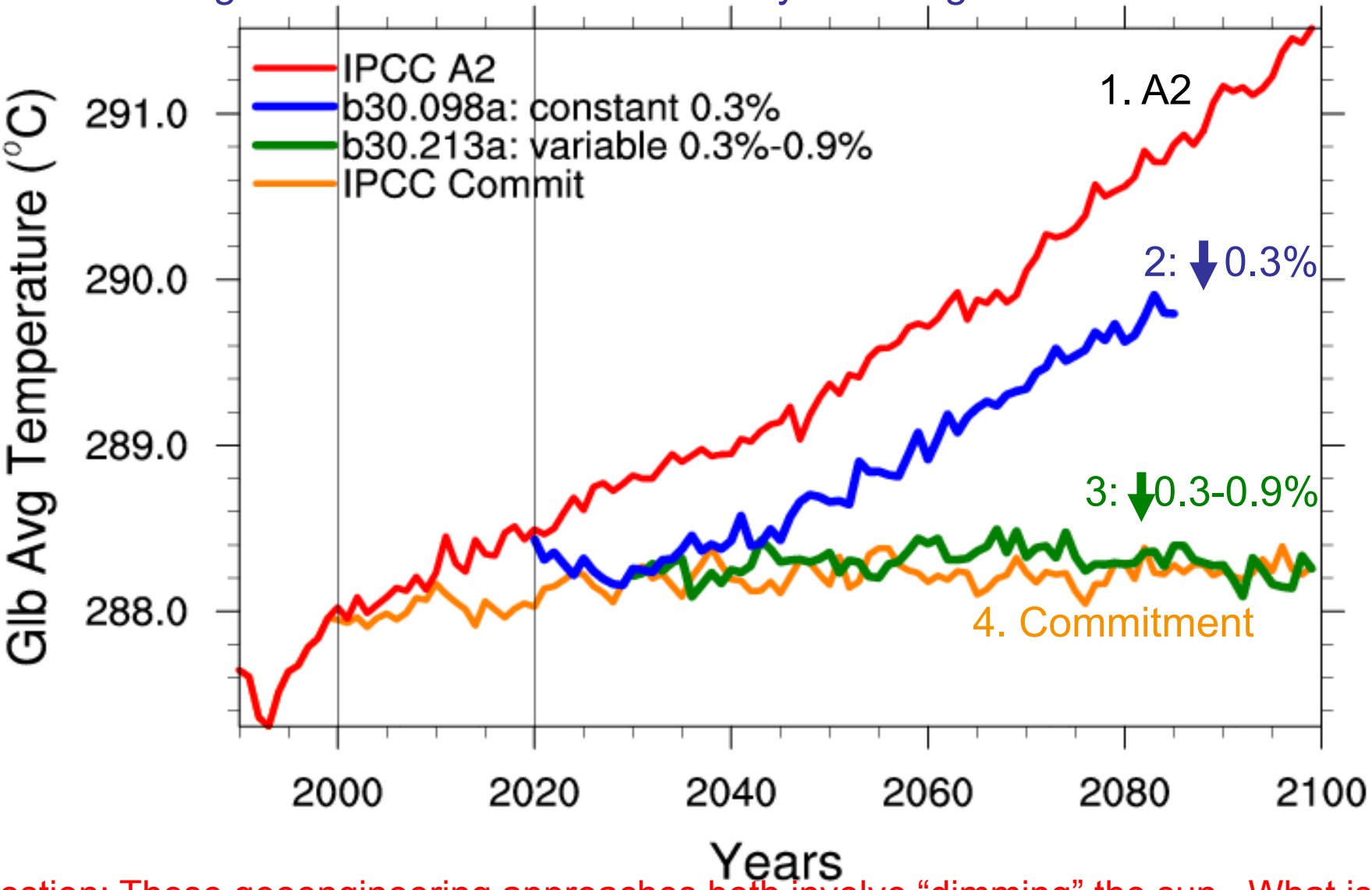


Solar Irradiance :
Latest Reconstruction and GeoEngineering



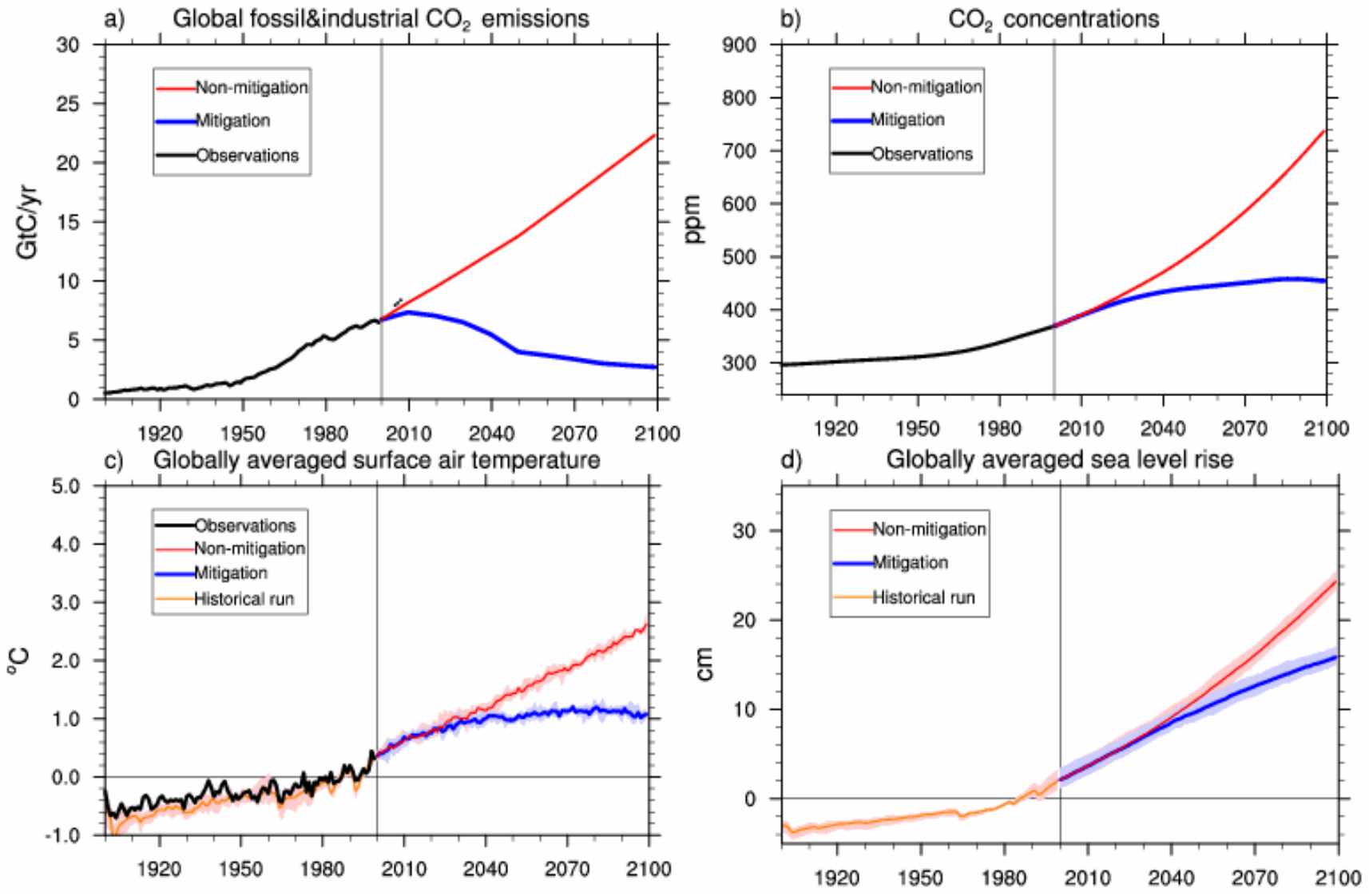
NCAR CCSM3 Geoengineering Run

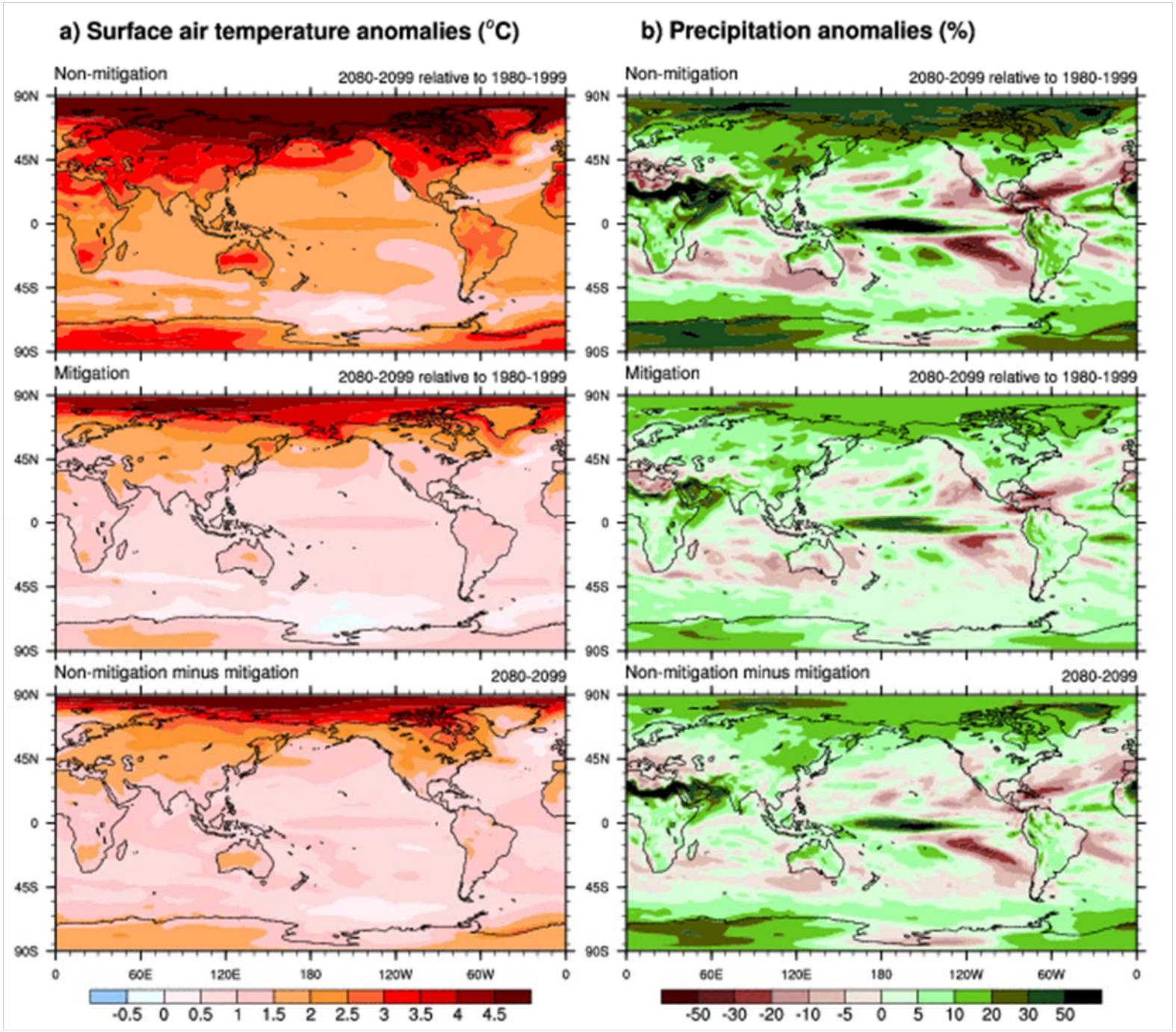
Maintaining A2 TS at commitment level by reducing solar irradiance

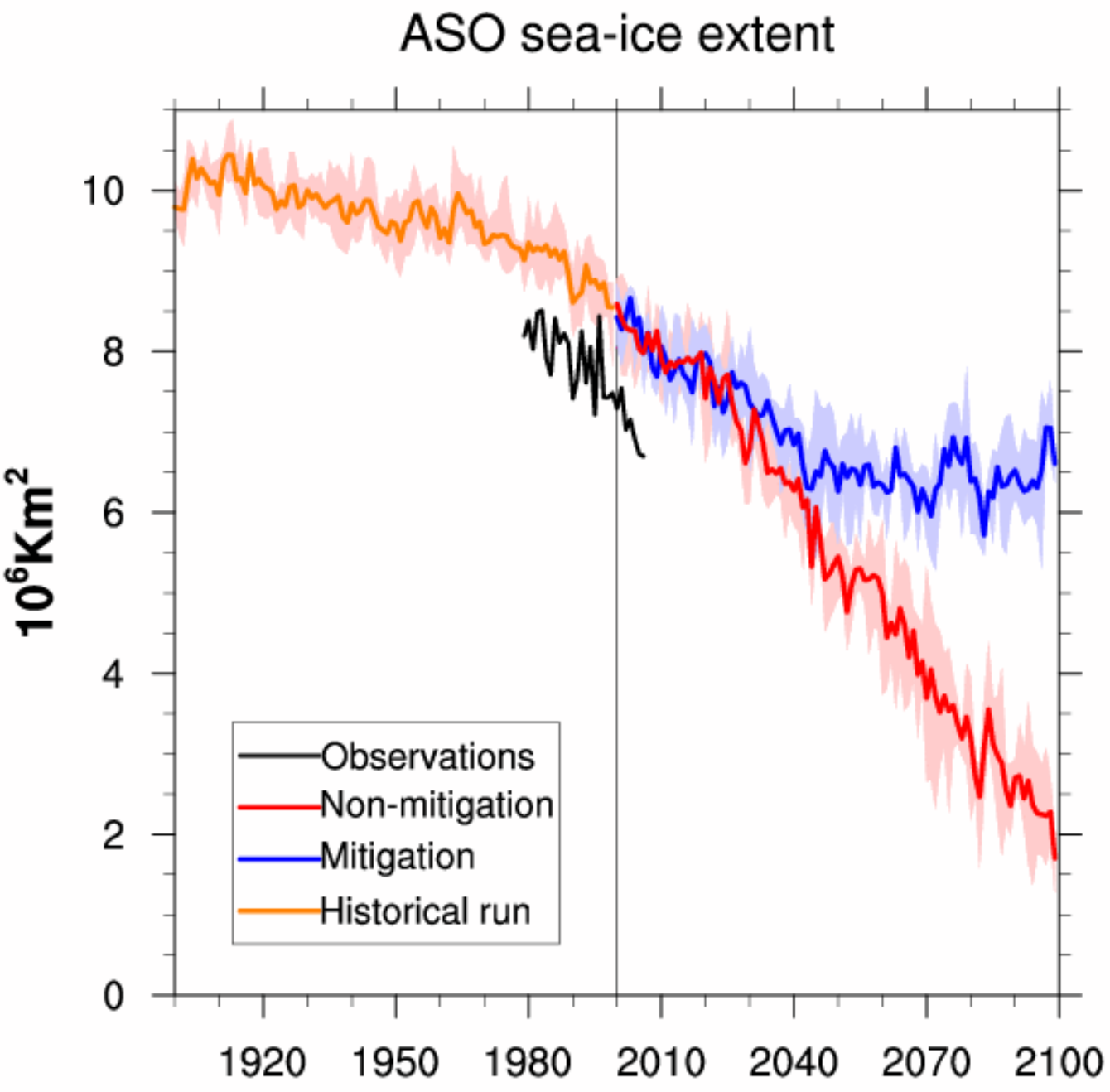


Question: These geoengineering approaches both involve “dimming” the sun. What is the impact on global food production of a 1% decrease in incoming solar radiation

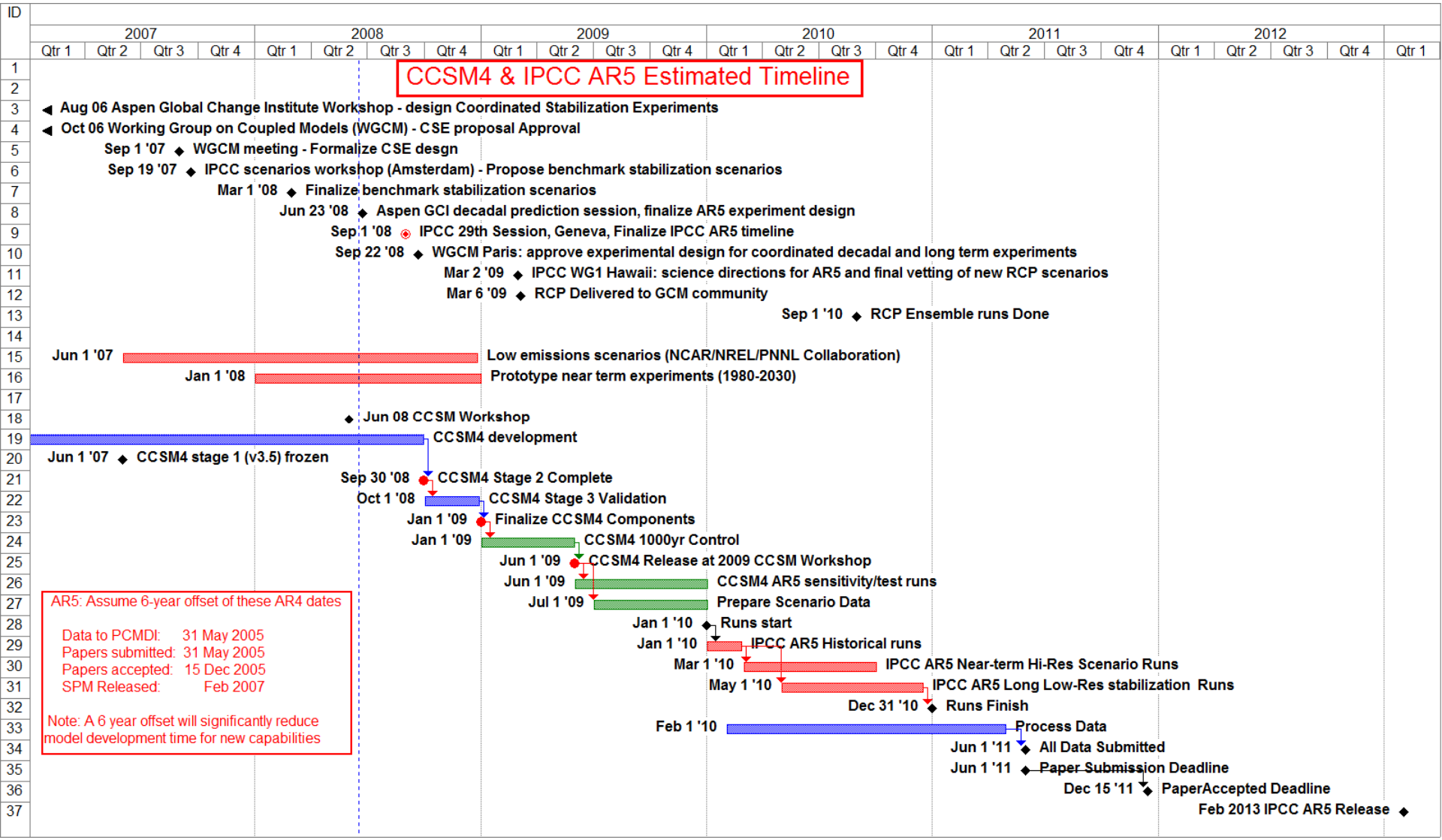
CCSP 2.1a Mitigation Simulations

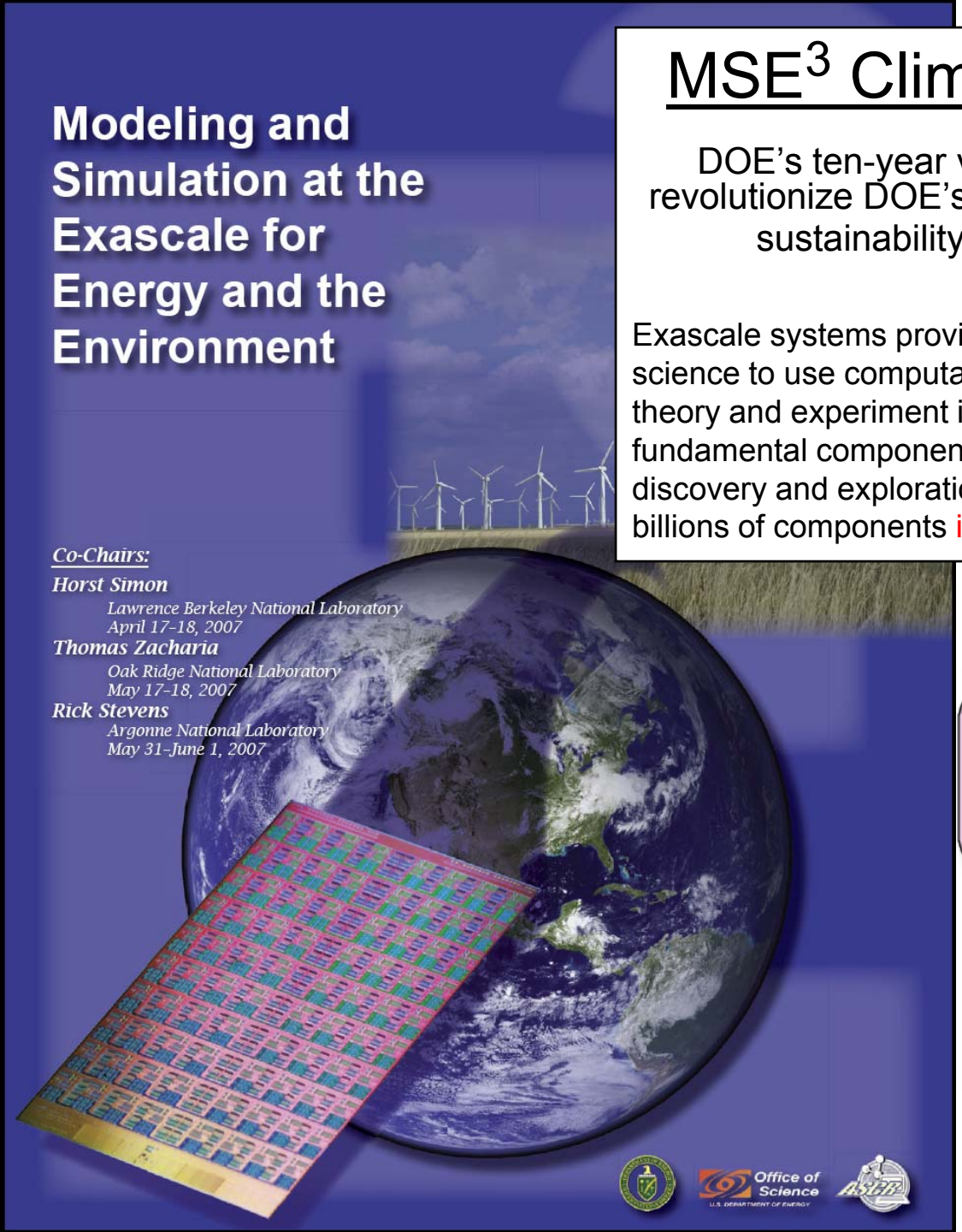



a) Surface air temperature anomalies (°C)
b) Precipitation anomalies (%)
Non-mitigation
2080-2099 relative to 1980-1999
Mitigation
2080-2099 relative to 1980-1999
Non-mitigation minus mitigation
2080-2099
90N
45N
0
45S
90S
0
60E
120E
180
120W
60W
0
-0.5 0 0.5 1 1.5 2 2.5 3 3.5 4 4.5
-50 -30 -20 -10 -5 0 5 10 20 30 50


ASO sea-ice extent
10
8
6
4
2
0
$10^6 Km^2$
1920
1950
1980
2010
2040
2070
2100
Observations
Non-mitigation
Mitigation
Historical run

IPCC AR5 Timeline (NCAR CCSM4)

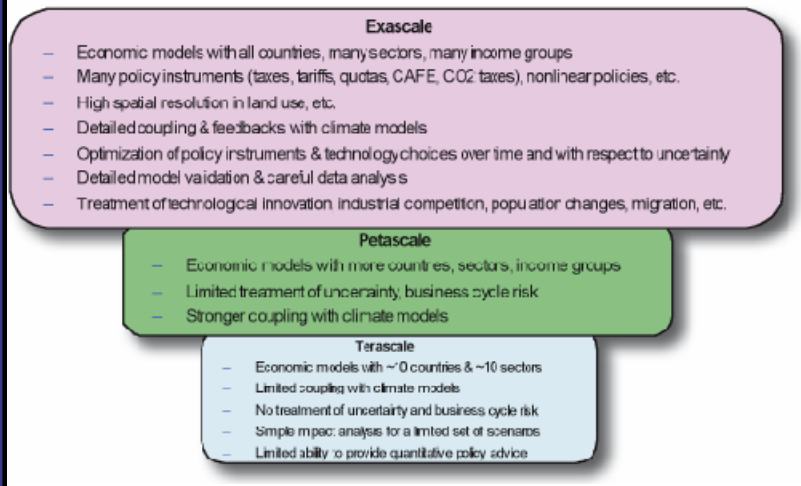




MSE^3 Climate Topics Summary

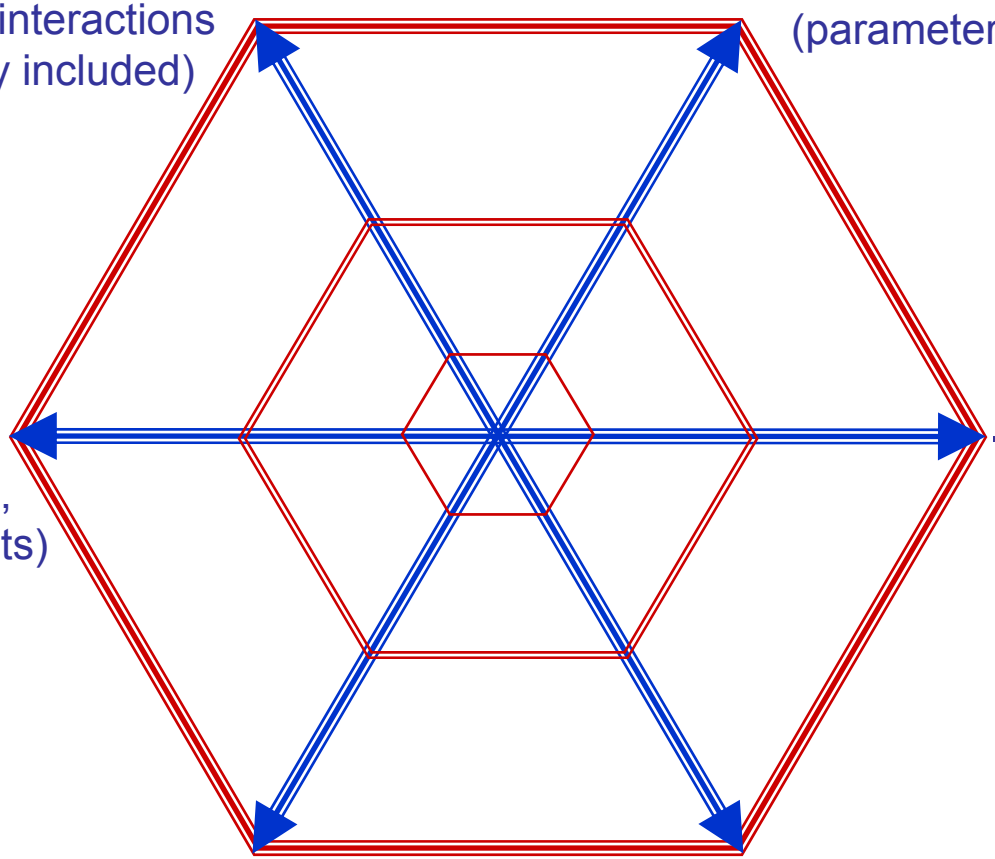
DOE's ten-year vision to use exascale computing to revolutionize DOE's approaches to energy, environmental sustainability and security global challenges.

Exascale systems provide and unprecedented opportunity for science to use computation not only as an critical tool along with theory and experiment in understanding the behavior of the fundamental components of nature but also for fundamental discovery and exploration of the behavior of complex systems with billions of components including those involving humans.



Download complete MSE^3 Report at
http://www.er.doe.gov/ASCR/ProgramDocuments/TownHall.pdf

HPC dimensions of Climate Prediction



New Science
(new processes/interactions not previously included)

Better Science
(parameterization → explicit model)

Spatial Resolution
(simulate finer details, regions & transients)

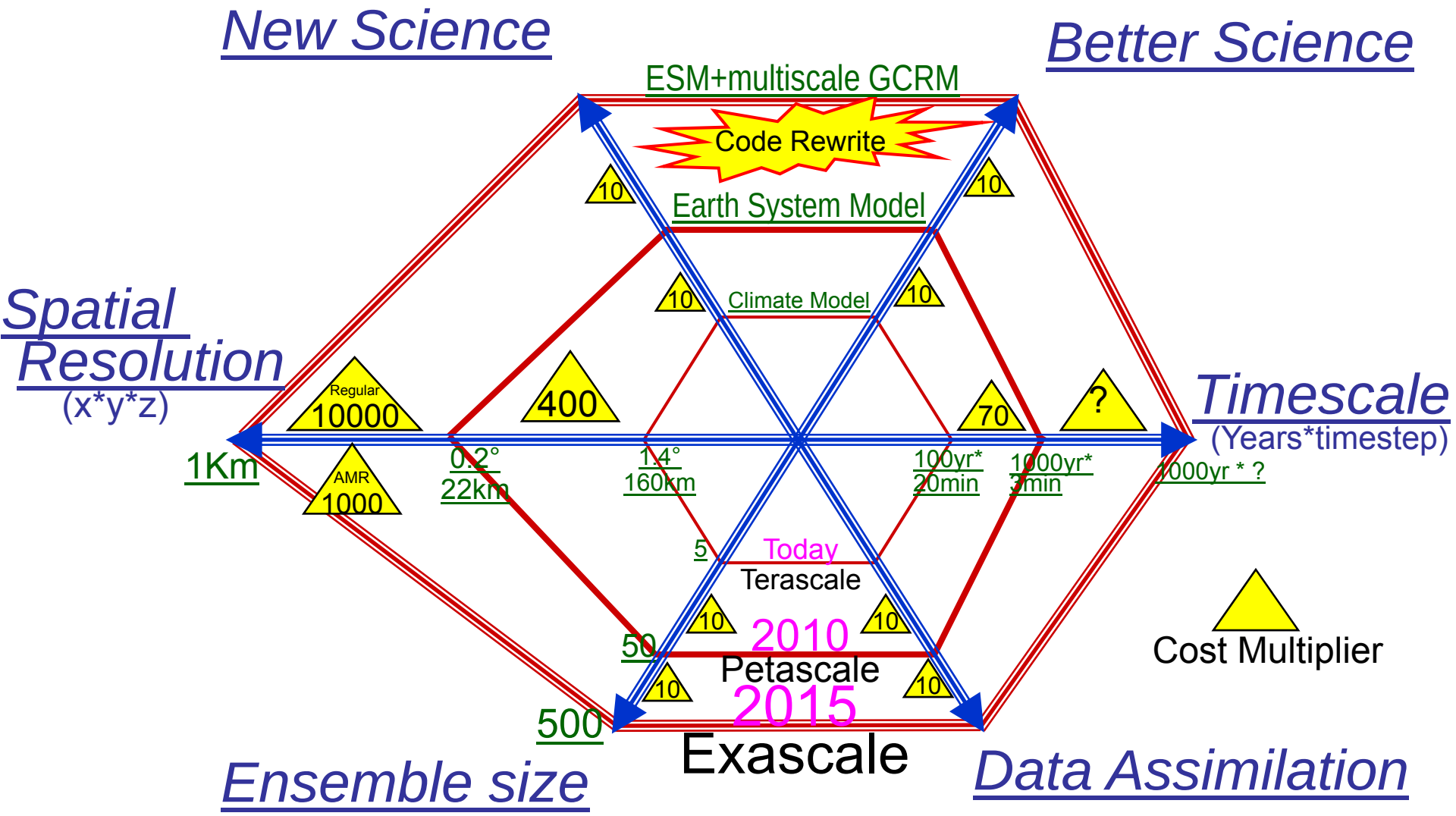
Timescale
(Length of simulations * time step)

Ensemble size
(quantify statistical properties of simulation)

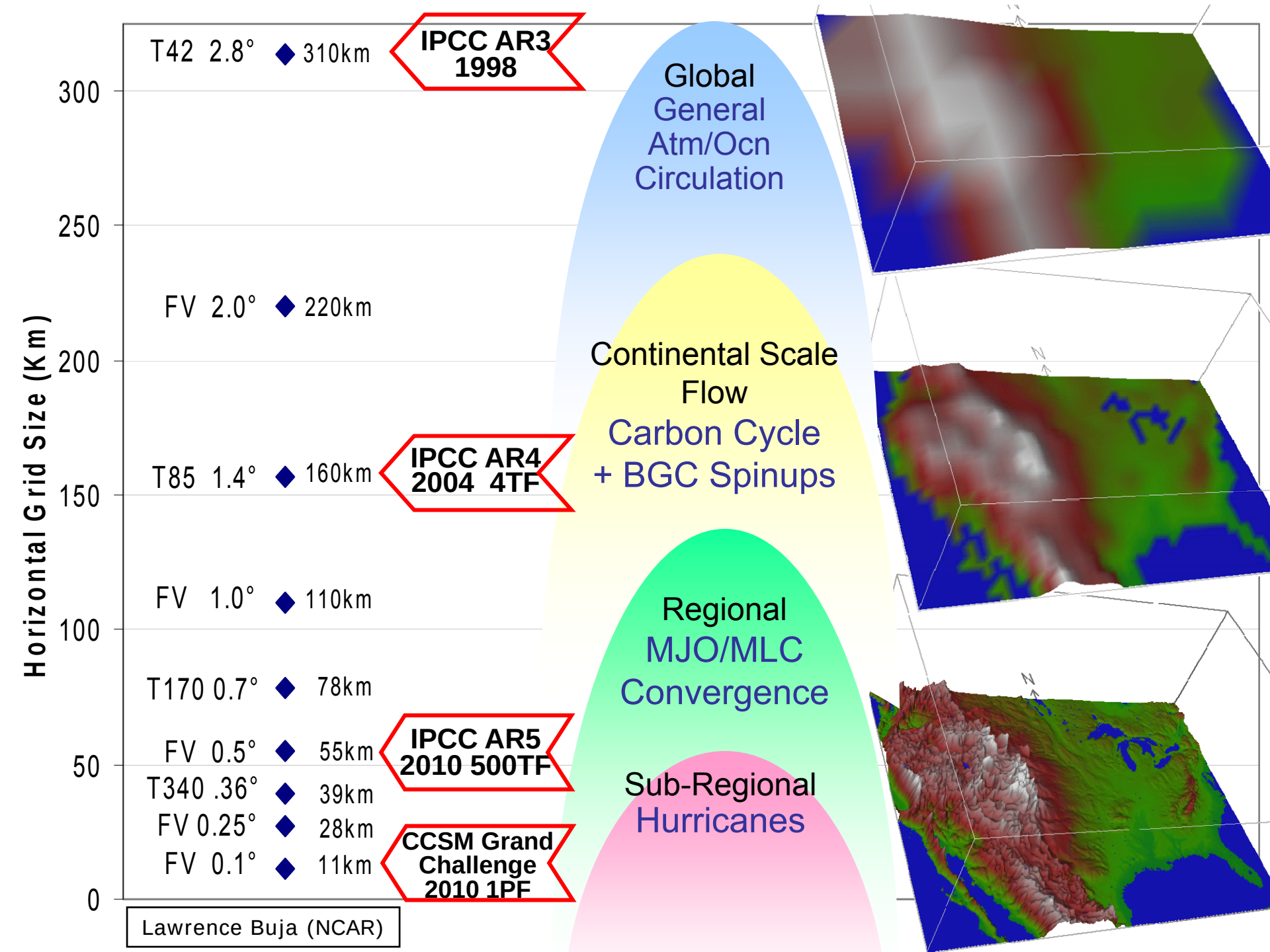
Data Assimilation
(decadal prediction/ initial value forecasts)

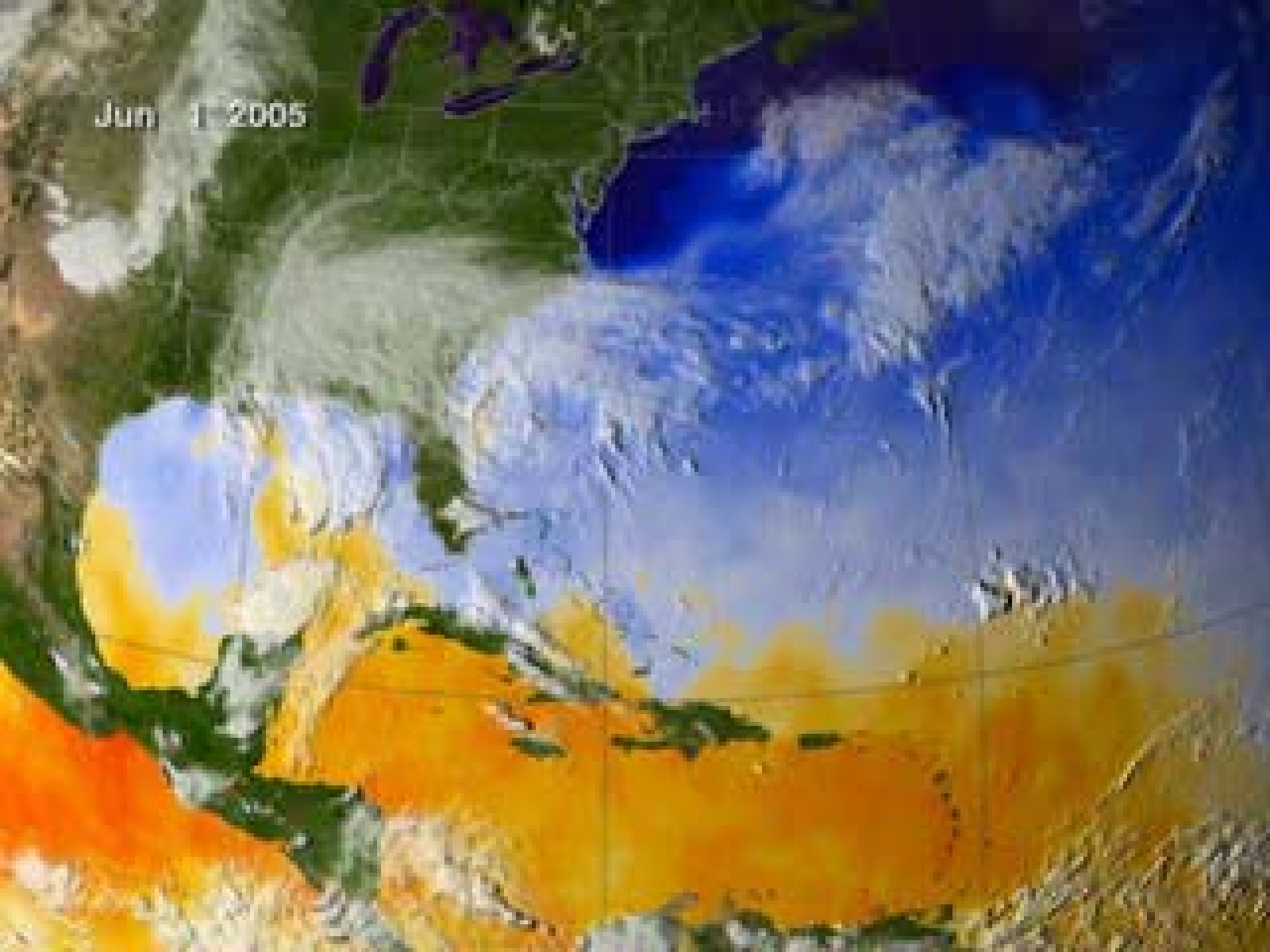
Lawrence Buja (NCAR) / Tim Palmer (ECMWF)

HPC dimensions of Climate Prediction

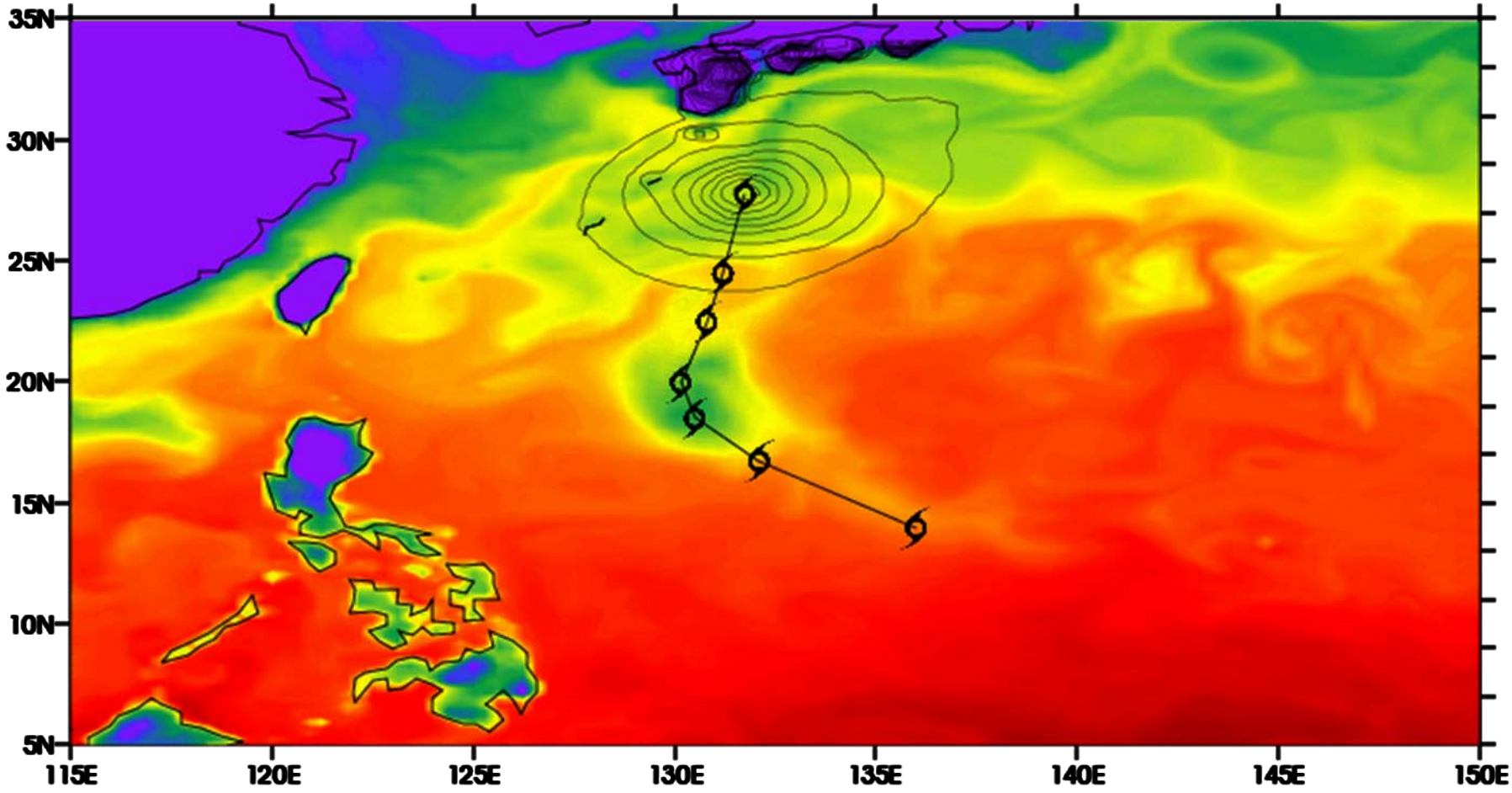


Lawrence Buja (NCAR)


Horizontal Grid Size (Km)
300
250
200
150
100
50
0
T42 2.8° 310km
FV 2.0° 220km
T85 1.4° 160km
FV 1.0° 110km
T170 0.7° 78km
FV 0.5° 55km
T340 .36° 39km
FV 0.25° 28km
FV 0.1° 11km
IPCC AR3 1998
IPCC AR4 2004 4TF
IPCC AR5 2010 500TF
CCSM Grand Challenge 2010 1PF
Global
General
Atm/Ocn
Circulation
Continental Scale
Flow
Carbon Cycle
+ BGC Spinups
Regional
MJO/MLC
Convergence
Sub-Regional
Hurricanes
Lawrence Buja (NCAR)


Jun 1 2005

CCSM at ¼ ° ATM 1/10°OCN



Courtesy Dr. David Bader, PCMDI/LLNL/DOE

New CCSM Components for IPCC AR5

- **Aerosols**
  - Direct and indirect effects
- **Chemistry**
  - Radiative and air quality issues
- **Dynamic Vegetation**
  - Regrowth following disturbance
- **Carbon & Nitrogen Cycle**
  - Ocean & land biogeochemistry
  - Anthropogenic (transient) land use/cover
- **Land Ice Sheets**
  - Sea level Rise & Abrupt Climate change

IPCC AR5 (2013) Scenarios

The current model development timeline anticipates CCSM4 in 2009 in time to participate in the next set of internationally coordinated mitigation scenario experiments in 2009-2010 for a 2013 IPCC AR5 publication date

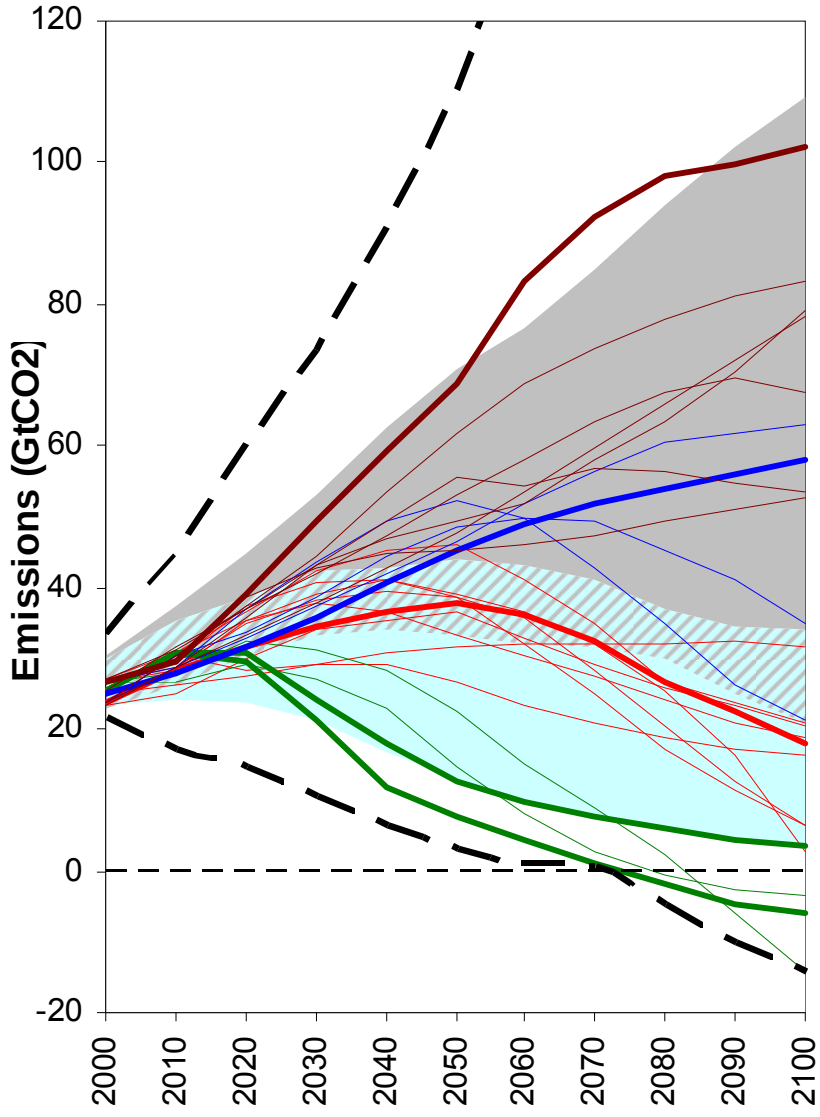
1. IPCC "Classic + " Mitigation Scenarios:

- 100 & 300-year climate change simulations
- Medium resolution
- Core "required" + optional Tier 1 and Tier 2 simulations
- Carbon, Nitrogen & Biogeochemical cycles
- 4 Representative Concentration Pathways (RCPs) from IAM community
- Quantify investment return of mitigation strategies

2. New Climate Change "Adaptation" Simulations:

- Short-term (30-year) climate predictions
- Single scenario
- High-resolution (0.5° or 0.25° resolution)
- Designed for impacts, policy and decision making communities.

RCPs in perspective – CO_2 emissions



MES-A2R 8.5 (900ppm, +4.5°, IIASA)

AIM 6.0 (671ppm, +3.7°, NIES)

MiniCAM 4.5 (550ppm, +---°, PNNL)

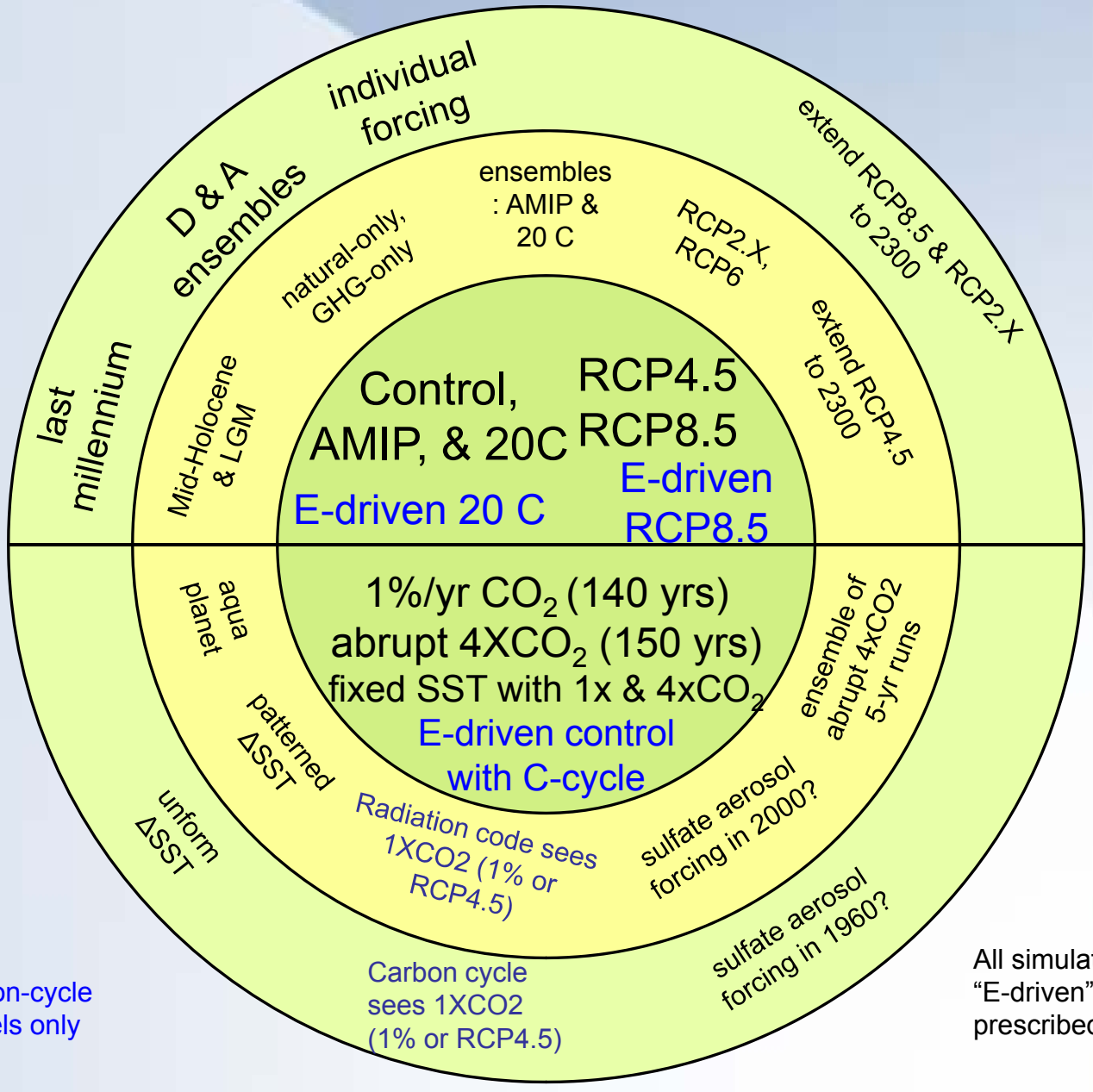
IMAGE 2.9 (424ppm, <2°, MNP)

IMAGE 2.6 (370ppm, <2°, MNP)

Stabilization range (10-90th percentile)
Baseline range (10-90th percentile)
Post-SRES (min/max)
Selected scenarios (min/max)

From Moss et al., 2008

CMIP5 Long-term Experiments

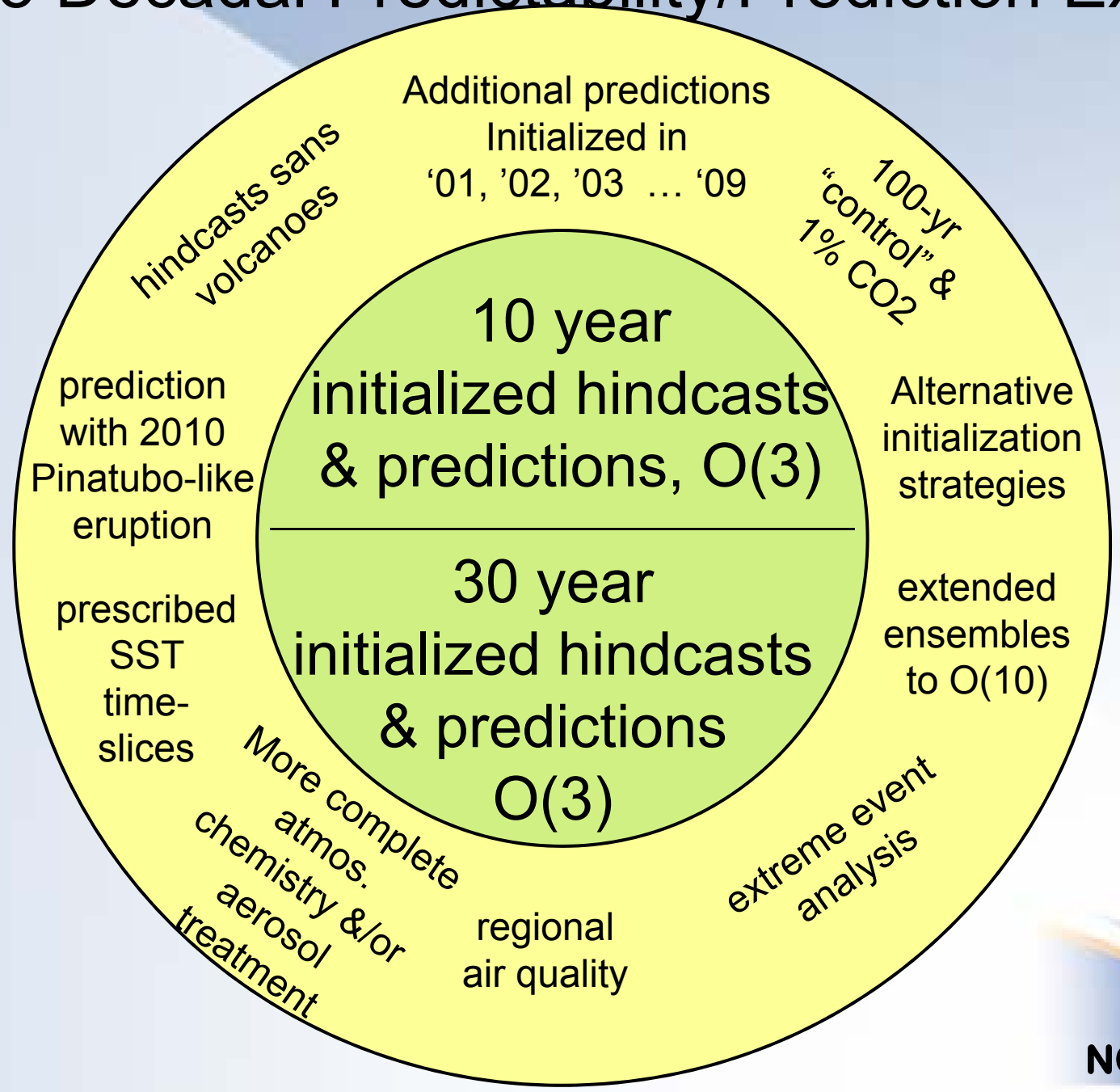


Coupled carbon-cycle climate models only

All simulations except those "E-driven" are forced by prescribed concentrations

NCAR

CMIP5 Decadal Predictability/Prediction Exps



NCAR

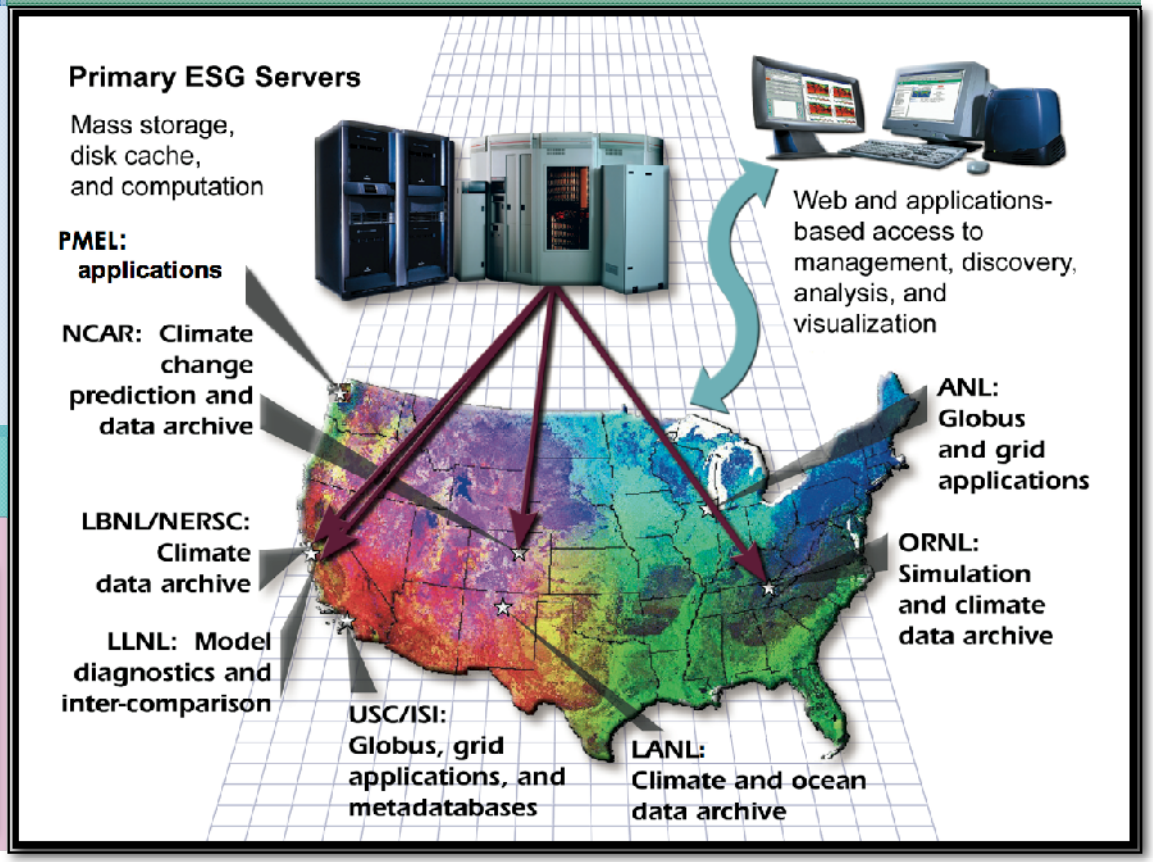
Earth System Grid Center for Enabling Technologies (ESG-CET)

ESG Goals

- Petabyte-scale data volumes
- Globally federated sites
- "Virtual Datasets" created through subsetting and aggregation
- Metadata-based search and discovery
- Bulk data access
- Web-based and analysis tool access
- Increased flexibility and robustness

http://www.earthsystemgrid.org
http://www-pcmdi.llnl.gov

Current ESG Sites

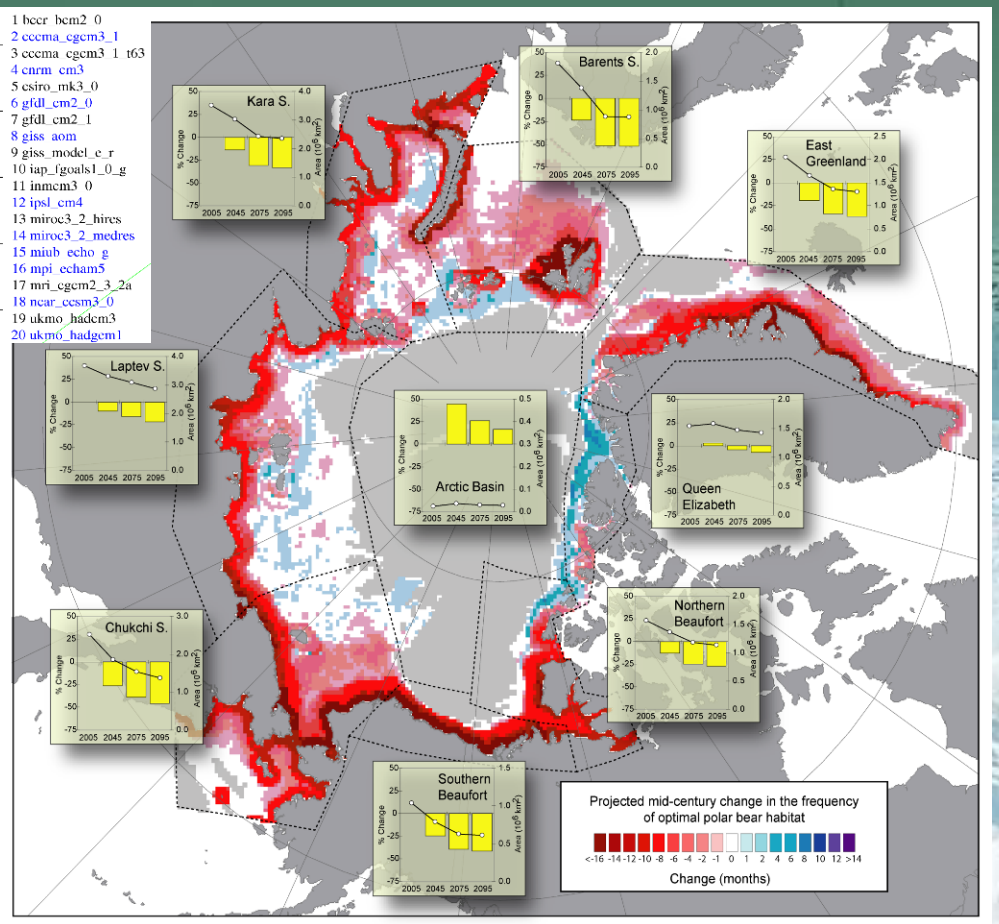


From: Earth System Grid Center for Enabling Technologies: (ESG-CET)

USGS
science for a changing world

Briefing on Results:

USGS Science Strategy to Support U.S. Fish & Wildlife Service Polar Bear Endangered Species Listing Decision:

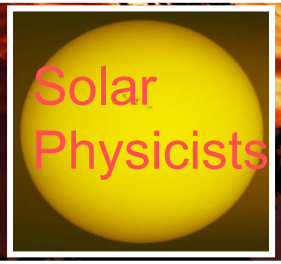


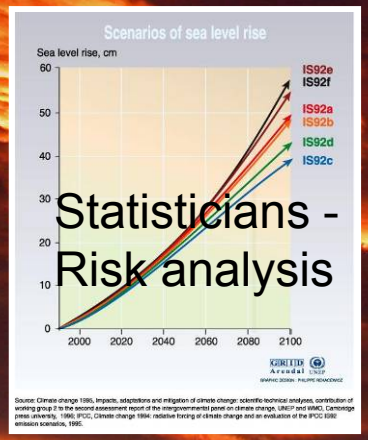
U.S. Department of the Interior
U.S. Geological Survey

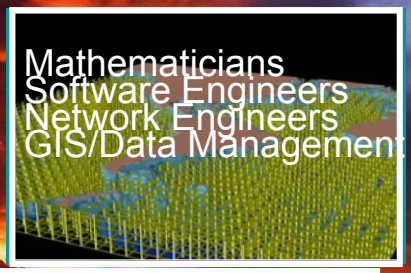
National Center for Atmospheric Research

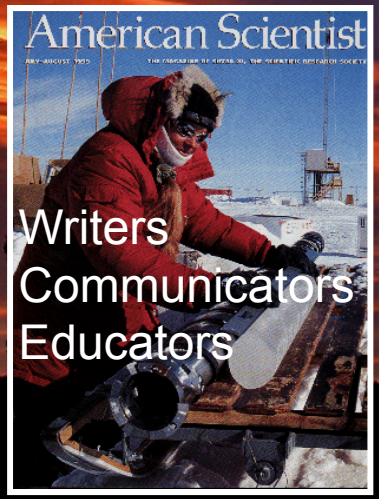
More than Meteorologists….

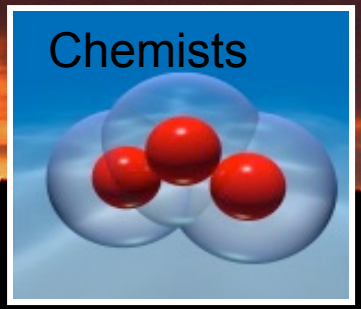
Weather











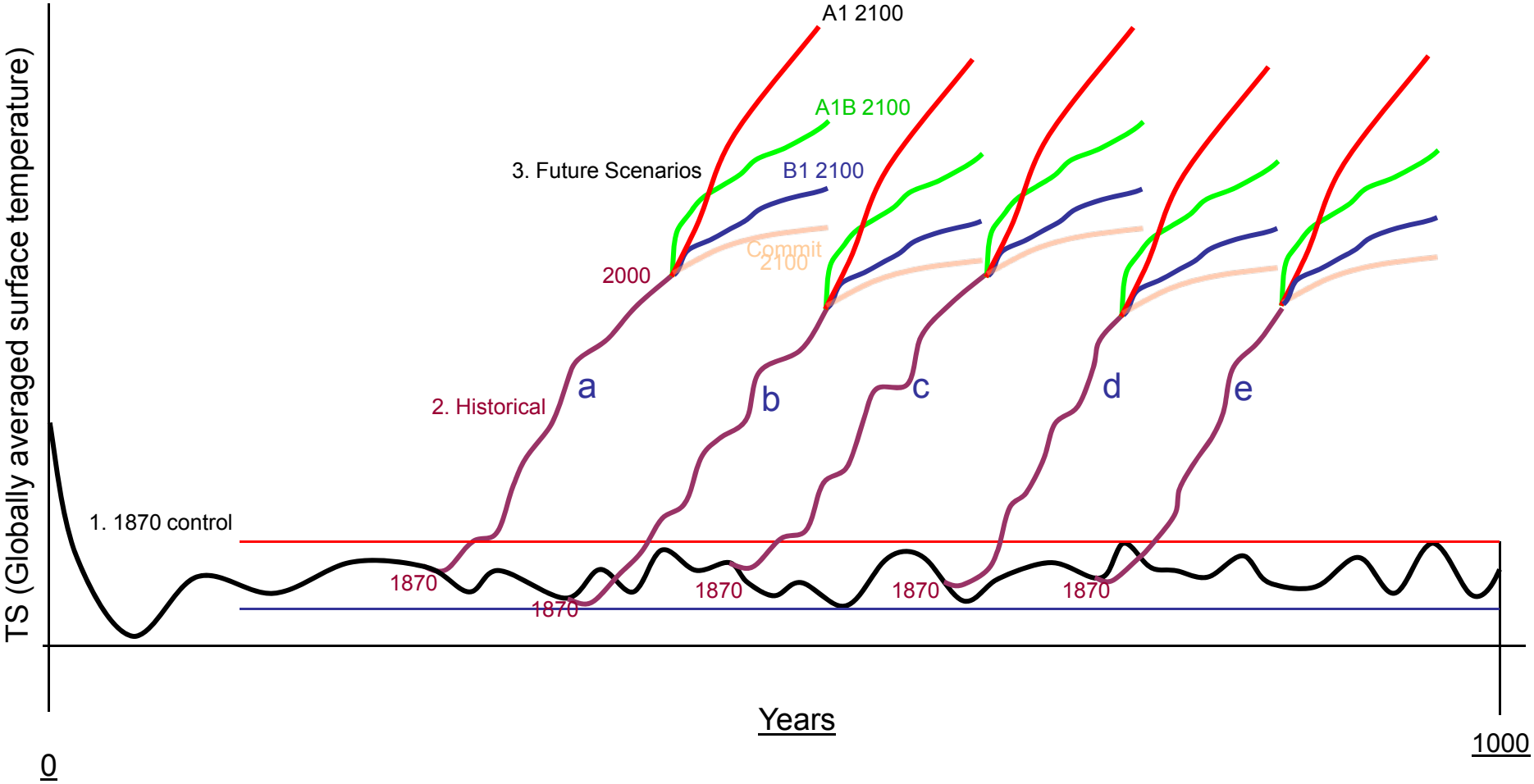
Thanks! Any Questions?

Probablistic Climate Simulations

Stage 1. 1870 control run: 1000 years with constant 1870 forcing: Solar, GHG, Volcanic Sulfate, O3

Stage 2. Historical: 1870-2000 run using time-evolving, observed, Solar, GHG, Volcanoes, O3

Stage 3. Future Scenarios: 4 2000-2100 IPCC Scenarios from end of historical run



Deterministic Climate Prediction